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PRINCIPLES OF
AUSTRALIAN AGRICULTURE

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PRINCIPLES

OF

AUSTRALIAN AGRICULTURE

BY

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A TRIBUTE OF RESPECT
TO AUSTRALIA'S FAR-SEEING PATRIOT PIONEERS
OF ADVANCED AGRICULTURE.

Spurned as "Cranks" and "Faddists," or at best derided as "Theorists" or "Dreamers," they ring-barked the forests of prejudice with the axe of reason, cleared the scrub of ignorance with the mattock of persistency, consumed the rubbish of obsolete methods with the fire of enthusiasm, and turned with the plough of research the virgin land of progress. Ridiculed or abused, and often in penury, they sowed the fields of Public Opinion with the seeds of new ideas, and we are reaping the harvest of their unselfish labours.

Thus the visions of the past become the fruitful realities of to-day, and the nation prospers.

PREFACE

IN 1892, the then Minister for Education and Agriculture in South Australia convened a conference of members of Parliament, the editors of the leading papers, agriculturists and educationists, to discuss the best means for promoting agricultural education. The writer was chairman of the committee appointed to draw up a scheme. Among the recommendations adopted by the conference was one affirming the necessity for a text book on Australian agriculture.

The duty of preparing such a book was many times urged upon the writer, and he in turn endeavoured to induce others to undertake it; but after nearly twenty years the work remained undone. The author has now attempted to meet the want. The task has proved even greater than was anticipated, for new ground had to be broken with no examples to follow or avoid. In addition, the requirements of at least three classes of readers had to be considered within the limits of one small book. If the writer has not wholly succeeded, his effort may at least stimulate others, and make the way easier for them.

The writer desires to acknowledge the assistance he has received from all who have by advice and criticism aided him in his work. The official journals of the various Departments of Agriculture have been utilised. The Commonwealth Bureau of Meteorology has taken much trouble in furnishing data in regard to temperature questions. Professor David, of the Sydney University, kindly assisted with advice about the geology of New South Wales, and the Government Geologist of Western Australia, Mr. Gibb Maitland, rendered similar assistance with regard to Queensland and Western Australia, while to his old teacher of geology, the late Professor Tate, the author is indebted for his general knowledge of the geological history of South Australia and Victoria. The writer is of opinion that the importance of geology to agriculture is not appreciated as it should be. The relation of chemistry to agriculture is generally recognised, and the writer desires to acknowledge his indebtedness to Mr. A. E. Mann, Government Analyst and Agricultural Chemist for Western Australia, for help and advice. The mechanical analysis of soils, and the importance of a study of their physical conditions has not yet received the attention it deserves, and the work now being done by the chemical branch of the Department of Agriculture in New South Wales in connection with the relationship between the chemical and physical properties of soils and their geological origin should be more widely extended in all the States.

The author has been in touch with the various Departments of Agriculture for many years, and has found the field experiment work of the officials helpful in explaining the general results obtained by farmers. He has also received much help from time to time from Mr. D. M'Alpine, Government Vegetable Pathologist, and Mr. C. French, Government Entomologist. One pleasing feature in connection with the work of specialists in Australia is the fact that they do not recognise State boundaries when assistance can be given to anyone seeking information. The author is a native of South Australia, was brought up on a mixed farm, and since boyhood has been associated with its agricultural development. As a member of the Central Bureau of Agriculture, and editor of the *Garden and Field*, he has been in close touch with the progressive movements in that State.

Since the manuscript of this book was ready for the printer, Dr. Howell's work, *Soil Problems in Wheat Growing*, has been published and has been carefully studied. It is pleasing to find that the writer's teaching is in accord with Dr. Howell's conclusions, after many years of investigation.

The standard works on soils, fertilisers, and principles of agriculture have been consulted and where possible used. For the rest, the writer has relied on his experience and that of the thousands of farmers, in the various States, with whom he has come in contact either personally or by correspondence in the course of his work as lecturer and agricultural writer. To Sir Walter James, K.C., and Messrs. J. M. Hattrick, N.D.A., and Prescott Harper, B.A., he is indebted for reading the manuscript and offering advice and criticism.

W. CATTON GRASBY.

PERTH, *October*, 1911.

FOREWORDS

THE Scottish Agricultural Commissioners, who spent some seven months in Australia last year, have recently reported in very complimentary terms with regard to the attention given to agricultural education. They were impressed with the supremely practical character of the Agricultural Colleges, and state that "It is possible for Britain to learn much from the system of Agricultural High Schools in Victoria," which, by the way, was outlined and strongly urged by the writer in his evidence before the Victorian Royal Commission on Technical Education in 1900. The Agricultural High School movement is spreading, but there is at present no text book on Australian agriculture available for pupils, and teachers must either make use of English and American works or depend on lectures and the scattered literature of the official and other agricultural journals. The same want is felt in other directions. The Departments of Agriculture of some of the States conduct classes for agricultural teaching in the country districts. The Technical schools also devote praiseworthy attention to this all-important subject, and the absence of a text book is frequently mentioned.

Australian farmers are, taken as a class, progressive, and in their Agricultural Bureaux, progress associations, agricultural societies, farmers' associations and so forth, give evidence of a strong desire to understand the all-important as well as most interesting principles underlying their practical daily work, but those, who are willing to study and seek a text book, find that they must depend on English and American works.

There is throughout Australia, among many city men, a yearning to get " back to the land." This sounds strange in the face of the concentration of the population in the towns, but it is a fact. Some think of the property accumulated by many farmers, while others are largely influenced by sentiment. Their desire is for a simple country life, free from the worries of business, with visions of

> "The fall of waters, and the song of birds,
> And hills that echo to the distant herds."

The idea is good and should be encouraged in these days of rush and bustle, motors and telephones ; but not many are prepared to pay the price. Usually the determined man may get what he is prepared to pay for ; but many things besides money count. Most men who talk of the simple country life have in view the richly appointed pastoralist's country home, with most of the luxuries of the city plus plenty of horses and men to look after them, and miles of country well stocked with sheep ; or may be, more modestly, their aim is a comfortable commodious farmhouse, with a thousand or two acres of rich freehold land. After all, not many fulfil Pope's description :

> "Happy the man whose wish and care,
> A few paternal acres bound,
> Content to breathe his native air,
> In his own ground."

When such a man is found it is safe to say that the world will call him a non-progressive sleepy old fossil, or something to the same effect.

Leaving out the visionaries, whose ideas of farm life are based on a pleasant holiday in the country, we undoubtedly have many level-headed practical, thrifty men who seek to go on the land because it affords opportunities for earning a good living while enjoying the most healthy physical and moral life. Australia affords examples of thousands of such men who have attained success in various branches of agriculture, and there will be many more. Much of the splendid pioneering work of this new continent has been done by men who never touched a plough until they settled on the land to carve out a home in the primeval forest. The history of settlement in every State proves that adaptability, intelligence and industry, are better qualifications than mere routine experience on a farm.

Those who desire to make the venture seek books to guide them. The old pioneers had no such help in paving the way for the much more simple work of the present day, and the men going on the land cannot be too often told that the technical work of the farm, be it devoted to wheat growing and sheep, mixed farming, fruit growing, or market gardening, can only be learned by actual practice on the farm ; but the difference between the man who studies why, as well as learns how, and the man who is satisfied with "rule of thumb" and "follow-my-leader" methods is the difference between the old and the new agriculture. It is greater than that, for the old-time English farmer who did things as his father and grandfathers for many generations did them, worked under one set of conditions, and he was really guided by the accumulated experience of generations. It is true that he either never troubled himself about reasons, or if he did was often wrong: but the science of agriculture is largely the explanation of the methods of centuries. By accident, or through unavoidable circumstances, or through laziness, variations in the old recognised practices were continually being made by the old-time farmers, and when these gave good results they were tried again and adopted if proved good. If the old farmer stuck to his old ways he had usually good practical reasons for so doing. When the town man goes on the land with the conviction that he can "teach the cockie" up-to-date farming, he has no such accumulation of empirical knowledge. If he does not study the principles of agriculture he is working against unnecessary odds, and usually finds his capital vanishing more rapidly than his experience accumulates. To such, one would in all sincerity recall the couplet:

> "Example is a living law, whose sway,
> Men more than all the written laws obey."

Or, in other words, until they know better, they are wise to follow the methods of men with local experience.

This book is intended to help the man who is going on the land, and for that reason it deliberately omits any attempt to teach methods. The good ploughman can command, say, 8s. a day or its equivalent. A book is not needed to teach a man how to earn labourer's wages. Ploughing is a mere detail, absolutely essential, but a thing an apt man will learn in a very short time, but the principles involved in this and other tillage operations are far-reaching and not yet fully understood in all their relations. The point is, men often start to learn at the wrong end. They want definite positive advice how to destroy pests, what manure to use, and so forth. What they should want to know first is why certain things are pests and why manures are needed. This book has been written with this objective. Local experience is the guide as to just what to do and where, how, and when to do it.

Again, at the time of writing, immigrants are coming into Australia from Britain, America and elsewhere, at the rate of several thousands a week. Many intend to go on the land. Some have had experience elsewhere, but before that can be used it is necessary that they should understand Australian conditions. This they must pay for, because it is a natural law that man never gets something for nothing. Even when he wins a lottery or robs his fellow he pays, and often dearly. This book is intended to help such to understand the principles governing success. The practical methods which have been evolved to suit our Australian conditions, he must learn in the particular State or district in which he settles. The best way is to pay for experience by working for it, and the farmer who teaches a "new chum" is entitled to payment in diligent, honest effort.

The Departments of Agriculture in the various States have, from time to time, issued many excellent handbooks and special bulletins for farmers and fruit growers. The existence and availability of this literature has been considered in the preparation of this book, and readers are recommended to procure such publications. The author has endeavoured to avoid duplicating work which has already been well done.

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THEORY AND PRACTICE IN FARMING.

Farming an art and a business. We learn to do by doing. Would a man learn farming? He must learn it on the farm by the daily, weekly, monthly routine of farm operations. Would he be a fruit grower? He must learn his business in the orchard. Whoever learned to ride except on a horse, to swim except in water, to milk except by milking, to plough except by ploughing, to dig except by digging? Did a lad ever learn cricket except with bat and ball, or a man bowls except on the green?

A man never really knows a thing until he has done it. That is the first principle in practical agriculture; and the intending farmer must remember it all the time, or he will deceive himself, if not others. A man may know much about agriculture, so that he may write learnedly and accurately about it, and be no more qualified to be a farmer than a man who quotes Shakespeare is to write a play. Knowing about farming is not farming. It is necessary to emphasise this, because failure to realise the fact has led many city men astray, by tempting them to go on the land and to attempt to conduct farming operations by a book. Many, with the faculty for adaptability, do succeed, and there are many examples where they have made more successful farmers than men who have worked on farms all their lives, because brains and business ability count for so much more in farming than is generally admitted.

Value of scientific training plus practical work. When a young man with a well-balanced mind, trained on a farm, adds theory to his practical knowledge, the combination is of the utmost value. Every farmer thoughtful for his son's welfare should endeavour to give him this great advantage. The town-reared youth who takes a college course should follow that by going as a cadet on a good farm, where he will be drilled into the practical work under commercial conditions.

Where a really good agricultural college is not available, the parent desiring his boy to become a farmer should send him to a good technical school to study elementary chemistry, mechanics, geology and biology, as well as book-keeping, carpentry, blacksmithing, wool-classing and a little saddlery, the use of soldering irons, etc. He should then go on to a good farm as a cadet where the farmer will drill him into practical farm operations on commercial lines and see that he works hard. He should study good books on the principles of agriculture, manures, and so forth. Farmers who do not care to send their sons to an agricultural college, should make a point of sending them to a technical school.

Things are not yet quite as they should be in agricultural education, but good progress is being made. The scientifically trained man can, and if he be a teacher will, explain to the farmer the reasons for suggesting modifications of practice, and the practical farmer will bring his experience to bear in carrying them out. This will make a good combination.

In agriculture, as in other spheres of teaching, it is essential that the teacher or "expert" should place himself in the position of the men it is his desire to help.

On the other hand, it would help the farmer a good deal in his critical attitude towards the "expert" if he would consider the absurdity of the Government employing a man to teach the farmer how to plough, sow, reap or mow. In these things the farmer is the expert. Is it not rank absurdity to judge a man's knowledge of the composition, character and treatment of soils, involving years of study, by his capacity to do a day's ploughing, for which a capable teamster can be got for 8s. a day or less? Is it not very foolish to judge a man's knowledge of the composition and use of fertilisers by his ability to operate a drill, which an intelligent farm lad can do as well as a Professor of Agriculture. Is it quite wise to judge a man's knowledge of the principles of stock-breeding by his ability to ride a buckjumper or flick a fly from a bullock with a twelve feet stock whip?

A knowledge of the principles of agriculture is not essential to successful farming, but a knowledge of the proper practice based on these principles is. On the other hand, all the knowledge of a Professor of Agriculture will not ensure success in practical farming without the detail of thorough, timely practice, which the old-time farmer carried out without knowing why. Further, while correct practice will, subject to seasons, ensure good crops, it may result in financial failure without business methods.

The essentials of success. Modern, progressive, advanced farming requires:

1. Thorough, old-fashioned cultivation and rotation, with modern appliances and methods.

2. Sound business methods, which will ensure profits.

3. A knowledge of the principles underlying the old-fashioned practices. Such knowledge enables the farmer to modify and modernise his methods, and it gives his work all the interest of scientific research. It makes farming not only the most healthy occupation, from a moral as well as a physical point of view, but places it among the most intellectual walks of life, offering in Australia as good a chance of an independency, if not fortune, as any other.

Agriculture defined. Practical agriculture in any of its branches is a complex occupation. It is essentially a business with all the interests of a science, because it is systematised knowledge, and the various branches of science explain many of the principles on which success and progress depend. If it be necessary to make a definition of farming it may be said to be:

The art of raising products from the soil and the business of marketing them to the best advantage.

Three classes of products. Agricultural products may be roughly classed under three heads:

1. Direct products from the soil, such as wheat and other farm crops, including grass, fruit, vegetables, fibre plants, etc.

2. Secondary products in the form of the animals, fed on the direct products, together with their produce, such as wool and milk.

3. The more or less manufactured results of the classes 1 and 2, such as flour, bran, pollard, chaffed hay, baled straw, butter, cheese, bacon, wine, cider, dried fruits. Specialisation in this class has already reached an advanced stage, and is increasing. Flour mills, butter, cheese, and bacon factories, fruit canneries and evaporators, wineries, and so forth, already take the place to a greater or less extent of the old practice of home manufacture.

Primitive and advanced agriculture. In the evolution of our great agricultural industry, the pastoralist first used the natural crop of herbage on the land to feed sheep and other stock. The highest form is using the soil to produce crops, using the crops to feed stock, which will fertilise the land and produce high priced products, such as butter, which will return the greatest revenue, take the least from the soil, and cost as little as possible to convey to market.

Good farming increases fertility. The aim of advanced agriculture is to obtain the maximum profit from the products of the farm, and at the same time to increase the fertility or the producing power of the land. Is not that a most fascinating problem, worthy of the best men of the State? Is it not as worthy of the brain and muscle of the University man as law, medicine or commerce.

Will the reader particularly note that the aim is stated to be maximum profit from the products, not maximum products from the farm? The two things may go together, but often they do not. A champion aged show bullock, dressing 1700 lb., as a purely commercial article, is not as profitable as a young steer dressing 600 lb. The heaviest crop of wheat is not always the most profitable, for the profit depends on what it costs to produce.

Working on reserves. In nearly every virgin country the first settlers grow crops or stock, but do not farm. They draw on the accumulated reserve of soil fertility and move on. This is what has been going on during the history of the United States and Canada. It is what was done in the older settled parts of Australia. It is being done in many cases now. It is bad farming, but, within certain limits, provided the settler knows what he is doing, it may be good business. In any case it is a stage in the development of a new country.

If the system of soil robbing is clearly recognised, and is only carried on to the extent of turning some of the reserve fertility into working capital, with which to farm properly, it is good business, but beyond that it is bad. A man may settle on a thousand-acre block, and in the course of a certain number of years remove from it £5000 worth of produce, and leave it in a depleted, unprofitable condition. A farmer on the same land in the same time might take £7500 worth of produce and have the land in a more fertile condition than at first. This is the object of good farming—annual profit and the building up of capital in the shape of soil fertility and good equipment.

Force of habit and example. From what we have said it is evident that a clear distinction must be drawn between the merely routine operations of agricultural practice and the principles of agriculture. Theory is good, but routine work is essential.

The average farmer, stockman, fruit-grower, gardener, or other practical worker on the land in all parts of the world carries out certain operations at certain times in certain ways, simply because it is the custom so to do. The Australian, American, or English farmer may laugh at the Egyptian fellah for using the primitive wooden plough which his forefathers used in the times of Joseph, but the conservatism is only a matter of degree.

The Australian farmer, by virtue of the spirit of enterprise required to decide on and carry out a plan of emigration to the opposite side of the world, and in consequence of the experimental work necessary to enable him and his sons to carry on operations under absolutely opposite seasons and varied conditions, might be expected to be, as he probably is in many ways, the most self-reliant, intelligent, and progressive in the world. His greatest fault is using the soil as a mine from which he may extract money without regard to the future. But progress even among Australian agriculturists is of the "follow the leader" order. If we examine the history of any progressive movement, we find that it generally takes some time to induce anyone to test and adopt a new practice. When a progressive man does depart from the established custom, he is severely criticised, and it is only when neighbours see that the new method is profitable that they adopt it, and then they copy as nearly as they can without, as a rule, attempting to understand the principles involved. This fact shows us that the best way to promote progress is to teach the few progressive men and let their example influence the others.

Theory and practice. In the proper learning of a manual operation three things are necessary:

1. The theory on which it is based.
2. The theory of the work itself.
3. The practical operation of the work.

The first is not necessary for the workman to do good routine work. The second is learned while doing the work, but the operator often fails to recognise that there is any theory involved, and he performs the operation almost mechanically.

If the above be applied to the operation of ploughing we realise that there is much science involved in the construction of the plough so that it will do the maximum of work with the minimum power, and at the same time properly turn in the weeds, pulverise the soil, and do all that is possible for thorough tillage ; but this theory will not assist the ploughman in doing a good day's work. What the ploughman must know is how to adjust and operate his plough to get the most out of his team and turn over as much land as possible in a day. He does not stop to think why the plough does the work, but as a good ploughman he does study how to set his plough to do thorough work. The farmer engaging a ploughman does not ask whether the man knows why, but he watches to see whether he knows how, and while things go right that is all that is necessary.

It is when new conditions arise that the theoretical knowledge saves time, energy, and money. It is the aim of technical education to raise the workman beyond a human machine, but it cannot do away with the routine of practice. The agricultural student is too often content to know why and how without the drudgery of acquiring mechanical routine proficiency in the art of doing. The lesson he must learn is that it is the doing which produces the return from the farm. The lesson the farmer should learn equally well is that theory will not only help him over his difficulties, but will raise his work from mechanical drudgery to an applied science.

Practice ahead of theory. In agriculture, good practice is usually ahead of theory. The value of legumes in rotation was known at least 2000 years before the discovery of nitrogen-fixing bacteria, in 1886. Farmers practised fallowing before science taught the reason. The practice of liming goes back to the time of early history, but the reason why lime is good is a recent discovery. There are still many facts we know quite well, but we do not yet know the reasons. Science is yearly explaining some of these facts, and we need many more investigators to work out the problems. The thoughtful farmer must not stop his plough to investigate the many "whys" which are always passing through his mind as he goes through the necessary but often mechanical process on the farm.

There is an altogether good and wise general movement, "Back to the Land." It is the fashion at present for everyone to praise the farmer and his work. Town men talk farming at their clubs and lunch tables, and not a few of those excellent people who live on the farmer—we are making no reflections—are quite willing to give him advice about the science of agriculture and "up-to-date scientific methods." City men invest in farming lands, and start to teach the "cockie" scientific farming. They are apt to find their capital on fixed deposit in the "Bank of the Land."

It is necessary for the city man, who talks so glibly about "up-to-date scientific farming," to realise that the storekeeper, merchant, and banker estimate the science of the farmer by his ability to pay his bills.

It all amounts to this. There is no walk of life where the educated man is more needed, or where he will find greater scope for the best qualities of mind and body than on a farm; but we must never forget that culture of the mind will not cultivate the soil. High ideals of how to live must be associated with the art of getting a living.

It may be safely stated that the fundamental law of up-to-date farming is economical seasonable work on proved routine lines, and the rest depends on business aptitude. This is the law, and the profits are in the observance of it.

Experiment and research. The up-to-date farmer must experiment, and he must not be satisfied with the results of one year; but the average farmer cannot afford to waste his time and that of his teams pottering over plots. The wiser plan is to deal with strips in his field work, and any results which are not apparent to the trained eye, or which cannot be tested with the harvester, are, as a rule, but not always, not worth bothering about. There are exceptions: for example, potash may add bushels of wheat to the acre without apparently adding to the straw. At the same time, the observant farmer would notice the extra weight of the ears of wheat.

Exact experimental work must be done by specially trained men with an aptitude for it, although some of it can and should be done on farms under the eye of the farmer. This, however, is the final stage, and before that is reached much patient work has to be done at specially equipped stations, where close watch may be kept over every detail.

Associated with and inspiring the experimental work is the research laboratory under technically trained men. It is, however, not one in a score of these who can be trusted to go among the farmers without creating a spirit of distrust in science. It is not an uncommon thing for the laboratory man to develop an ambition to go and teach the farmer, but as a rule the result is disastrous to the confidence of the one in the other.

The interpreter. Between the research worker and the farmer there is a great gulf fixed, only now and then bridged by the scientist who is a popular teacher. Usually the scientist requires an interpreter, and this position is filled by the popular lecturer and well-conducted farmer's newspapers. The agricultural press is, unfortunately, often as full of errors as the farmer's crop is of weeds; but it has been and is the most important influence in agricultural education. The popular lecturer is often popular in proportion to his technical inaccuracy, and his aptitude for humorous or striking illustrations; but he sows seed of thought, and prepares the way for further teaching. It is well for all who desire to teach to remember that no one can be taught that which he is not in a proper condition to learn; and that as the pupils cannot reach the level of the teacher, it is wise for the teacher to try to get down to the level, of his pupils.

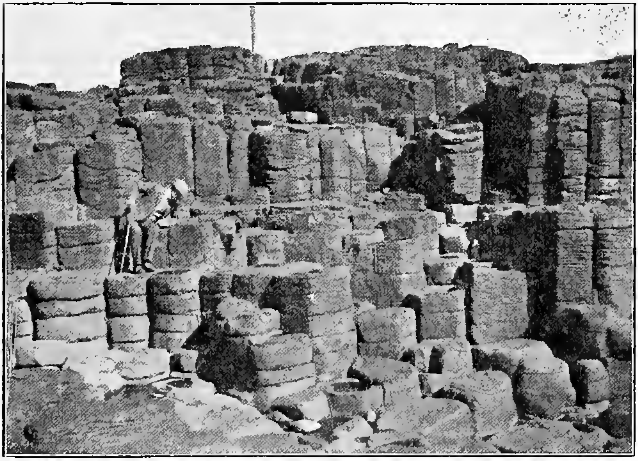
THE SOIL, ITS ORIGIN AND NATURE.

Soil, the home of plants. Many agricultural terms are difficult to define exactly. One minute we may speak of the earth, meaning our planet; and in the next refer to a handful or a load of earth. A man may talk of buying a thousand acres of land and his friend may at once ask him whether his land is loam or clay. One farmer may speak of cultivating the soil, another of ploughing the land, a third of digging the ground, a fourth of shovelling earth, and the four mean the same thing.

The soil, the earth, the ground, or the land supports plants, animals subsist on plants, and the waste from their food as well as their bodies themselves, when they decay, go back to the land as manure. This general statement broadly expresses the rotation of nature on which agriculture is based. The soil is only one of many factors in the growth of the farmer's crops, but it is a very important one. It is in a sense his workshop and his raw material. We therefore have to consider, among other things, Whence came the soil? What is soil? How and why it varies? What principles are involved in cultivating it? and many other questions.

Whence came the soil? In answering this question we have to go far back in the history of our planet; or, in other words, to understand the origin of soils, the student must know a little of geology. He must realise that at the present time and far back through countless ages the earth's surface has been undergoing processes of building and destruction, of making and unmaking. Some of the agencies are violent, aggressive and easily seen; others are unobtrusive or actually hidden. On the one hand we have a volcano belching forth lava and volcanic ash, covering miles of the earth's surface with material which in the course of ages becomes fertile soil by the agency of weathering, chemical change and bacterial life. All that we can do in a general limited book like this is to give a very simple outline of some portions of the subject which affect practical agriculture.

Soil derived from the decay of rocks. It is usual to say that soils are formed by the decay of rocks, and that is in the main true; but there is an essential difference between decomposed rock and fertile soil, which an illustration may serve to explain. What the Australian bushman calls damper is unleavened bread, made by mixing flour, water and a little salt into a dough and baking it in the ashes of the camp fire. The same ingredients mixed in the same way but with a small quantity of yeast and a few hours for the yeast to work produce bread. The damper differs from the bread very little in composition but very much in texture, digestibility and palatability. The essential difference between the damper and the bread is due to the action of the yeast, a single-celled microscopical plant which gives rise to comparatively slight chemical changes, but the carbonic acid gas produced separates the particles of dough with bubbles of gas and makes the bread light or open in texture. The point we wish to illustrate is the fact that the change from unfertile decomposed rock to fertile soil is largely due to living organisms, many of the most important being microscopical plants called bacteria.



Basalt, Burnie, N.W. Tasmania.
One source of first-class soil.

Factors determining the character of soil. Put more definitely, an ordinary soil is a complex material, the basis of which is decomposed rock. Its character is affected by, first, the chemical composition of the rock from which it is derived; second, the degree of grinding and chemical change it has undergone; third, the amount of washing to which it has been exposed; fourth, the amount and nature of the organic matter, *i.e.* decayed animals and plants incorporated with it; and, fifth, the microscopical life it contains.

Sand is ground rock from which the finer particles have been washed out. Clay is also ground rock and is composed of the fine particles washed out of the sand. Peaty soils are almost entirely composed of decayed or decaying plants. These extremes are not good soils. The farmer desires a soil which is composed of all three; but the mixture may vary in character. Terms are loosely used. If sand predominates, the soil is sandy. If clay is the chief constituent it is clayey. When vegetable matter predominates the soil is peaty. And when the three are more evenly mixed we have the varied series of loams so highly prized by all classes of agriculturists. Later on it will be necessary to be more exact, but this much is necessary to prepare for the study of how soils are formed.

Ancestry of soils. Were soils gifted with the weakness of men some would no doubt be equally vain in claiming superiority on account of their origin, and certain it is that the ancestry of a soil is of vast importance to the man who has to cultivate it. Admit this personality and imagine the aristocratic air of the rich chocolate volcanic soils of Warnambool, Ballarat, Mount Gambier, Colac, the Liverpool plains, the Darling Downs, and Northern Tasmania, as they boast their descent direct from old Pluto, and glory that in their birth the very earth shook and trembled. Think of the rivalry of the rich alluvials which might with equal right claim to be the result of the erosion of ten thousand hills which were old when Mount Gambier and other extinct volcanoes started into activity.

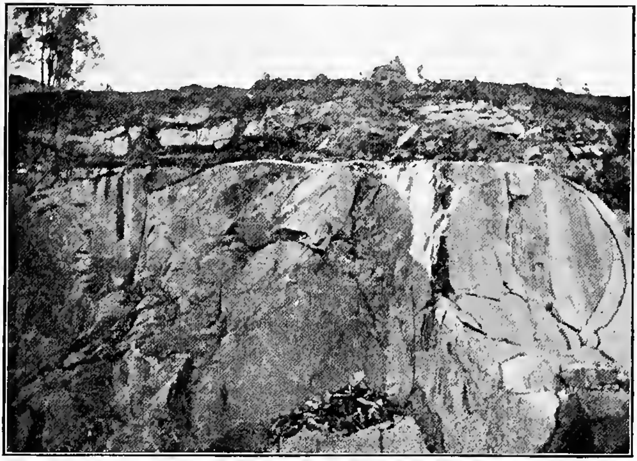
Science involved in the study of soils. The point we desire the student to realise is that in considering the origin of soils as well as some other questions underlying agriculture, we cannot draw a clear distinction between supposition and fact ; in other words we do not quite know where reality ends and imagination begins. The study of the origin of soils is largely a matter of geology, and the charm of geology owes much to the imagination of the geologist. In addition to geology the origin and composition of soils involve the study of chemistry, biology, physics, meteorology, and so forth.

It is important that the student should get a good grasp of this question of the origin of soils, but it must be candidly admitted that the knowledge will help the farmer but little in his daily business of getting a living from his farm. It will explain many of the whys of his work, but if he keeps his plough idle while he studies the origin of the soil, he may obtain pleasure and knowledge but he won't get crops. Cultivation of the mind is not a substitute for tillage of the soil. Many a farmer has failed, not from knowing too much but from doing too little. Study why, but keep the teams going,—that is a fundamental principle in successful farming.

The close relationship between rocks, soil, and vegetation. The visitor to the city of Adelaide sees a range of hills from five to ten miles distant, and if he has studied the origin of soils and their relations to rocks and vegetation he will guess the general character of the rocks forming the separate hills, the soils overlying the rocks, and the general character of the vegetation without going near them.

Further, tell such a man the chief rocks of Northern Tasmania are shales, quartzites, granites, together with extensive areas of ancient lava beds and still more ancient diabasic rocks, and, provided he understands the climatic conditions under which they were formed, he will tell you the range of soil to be expected there. Describe to him the geology of any given district of Victoria or New South Wales and he will give you a very good idea of the chief characters of the soils. Tell the geologist that there are immense areas of Western Australia where the only rocks to be found are granite and concretionary ironstone, with frequent dykes or intrusions of diorite and diabase, and he will, subject again to the influence of climate, give a generally correct description of the soils he would expect to find.

Soils of transport. The above remarks apply with great accuracy to soils which have originated where or near where they are found. They do not apply to such soils as those of the Adelaide plains, the Murray Valley, the coastal district of Western Australia, the rich alluvial soils of the River Hunter, river valleys in general, and the drained beds of ancient lakes and seas. Such soils belong to different classes, but all possess one common characteristic. They are transported soils. They are the soils of mixed ancestry. There is no line of pure descent, unless it be the literal one of being washed down from higher to lower levels. They are the migratory sections of the soil family, a mixed race, and often of great fertility. Running water has in most cases been their nurse or foster-mother.



A Granite Quarry Face showing the transition from Rock to Soil.

Transformation of rock to soil. If the student would understand the origin of soils he must read the story told in a quarry or railway cutting. With many variations this is what he will find. The surface soil is usually more or less dark in colour, and is interlaced with the roots of plants growing in it. From the surface downwards it changes in colour and also in texture until at a short distance measured in inches it assumes the character known as subsoil. This subsoil may be of varying depth, and as one follows it down he finds that it gradually changes. We are speaking of soils *in situ* and not of alluvial or transported soils. At a short distance from the surface the subsoil becomes semi-decomposed rock, surrounding stones of varying sizes. A little lower down it is broken rock, with pockets of rotten or decomposed material. Lower still the more or less solid rock is reached, but even here there are seams of soft material following the irregular courses of the cracks and bedding of the rocks. Down these seams or cracks the roots of shrubs and trees pass, and they assist in widening them.

In a quarry near Adelaide the writer measured roots of eucalyptus trees eighty odd feet from the surface, and for seventy odd feet the quartzite rock was being quarried for road making. In Western Australia tree roots are met with at much greater distances from the surface in the caves in the limestone rock. The details in each quarry or cutting will vary, but everywhere there is the same gradual transition from solid rock below to more or less fertile soil on the surface; but if the student desires to understand this process of soil-making he must watch for himself. To remember the facts as stated will load his memory, but teach him nothing real.

The materials which form soils *in situ*, when carried by water and wind and deposited elsewhere, form transported soils and alluvials.

THE AGENTS OF ROCK DECAY AND SOIL-MAKING.

We have now to consider what are the agents which change solid rock to soil material and this again into fertile soil. These are many and varied, but may be broadly classed under three heads :

1. Mechanical, or the Mills of Nature.
2. Chemical, or the Laboratory of Nature.
3. Biological, or the Nursery of Nature.

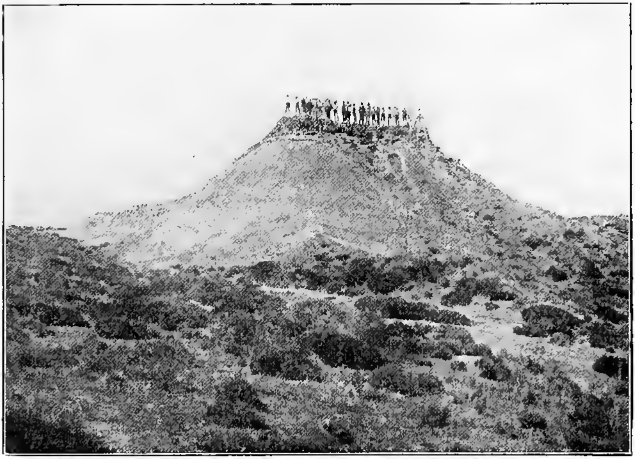
It must always be remembered in the study of nature's processes, that although we may tabulate them as above, they cannot be so separated in operation. The varied agencies work together and help one another. From the time that the surface of the earth cooled, making a solid crust, it has been acted upon by air, rain, frost, heat and cold, ice and running water, chemical action and living organisms.

From the beginning of geological time, the processes of making and unmaking, change and decay, life and death, or more correctly life in death have gone on.

Denudation by water and wind. The convulsions caused by the cooling and shrinking of the earth's crust formed the mountains, but other agencies have ever been at work wearing them down. The whole surface of the earth is being slowly levelled. The late Professor Tate estimated that the Mount Lofty range near Adelaide, now 2400 feet high, must have at one time been as high as the Alps of Switzerland to have provided the huge accumulations of worn material forming the geologically recent beds overlying the same old rocks as form the basis of the hills.

The Dividing Range of Victoria and the Blue Mountains of New South Wales must have been similarly denuded. If the vast accumulation of material in the great basin of the River Murray and its tributaries be considered, and in addition the tens of thousands of square miles constituting the vast and geologically recent artesian basin of Western Queensland, New South Wales and central South Australia, besides that which has been deposited in the ocean, what a mighty chain of mountains would it provide. Given the geological imagination we can readily construct in the far distant past mighty ranges of mountains. If we take Western Australia, with its absence of anything worth calling a mountain, we have a vast accumulation of worn and transported material of unknown thickness between the Darling Range and the ocean sufficient to build a fine range of mountains.

Denudation and transport going on now. We must not think that this process of levelling is a thing of the past. It is going on to-day. Look at the material moved by each winter's rains or transported by the wind every summer. Before a dust storm the roads and streets may be thick with dust, after it is over they are often swept clean. In the northern agricultural areas of South Australia it is not an unknown thing for the whole surface of a well-worked fallow field to be blown away, when a hot north wind fills the air with blinding dust over an area of thousands of square miles. After such a storm the busy housewife may have to sweep up and remove buckets of dust and fine sand from in and around the house, and if we try to calculate what this means over thousands of square miles we see that running water is not the only big agent of soil transport. The whole surface of the coast



"OUTLIER," NOARLUNGA, S.A., SHOWING THE EFFECT OF DENUDATION.

The top of the hill shows a former level of the country. The mass of the hill is marly clay which washes easily, but the top is protected by a cap of travertive limestone.

country for many miles on each side of the Murray mouth is changing, owing to the destruction of the sand hill vegetation by stock and the movement of sand by the wind. The Coorong is rapidly filling up. On the coast of Victoria and of Western Australia the same thing is going on.

Effect of clearing and cultivation. If we travel over the agricultural areas of any of the States we see how the surface is changing owing to the removal of soil by water and wind. Where the pioneers cleared forest country less than half a century ago the winter floods have washed great gulches through fertile fields. The writer knows places where, when a boy, he saw fine fields of wheat, the land is now unworkable on account of the many washaways. In one he knows of a washaway through a rich alluvial gully a quarter of a mile long and big enough to bury a wagon. It follows the course of a drainage furrow and was washed out in one winter and chiefly in one night of flood.

In Western Australia, where vast areas of forest land are being yearly cleared, water courses are seldom seen, but they are forming, and in a few years they will be common. Plough furrows and wagon tracks often form the beginning of great washaways.

Unceasing change. We see then that soil is never at rest for long. It is constantly receiving and constantly giving. It is added to by the decomposition of the rocks below, and above by the decay of plants and animals and by deposits by wind and water. On the other hand the agencies of running water

A. Virgin Swamp Land.

B. The same class of Swamp Drained.

The foreground shows the peaty soil newly broken up, while beyond is a crop of Cauliflowers.

and wind are always robbing one place and giving to another or forming new deposits. Ponds and lakes are filled or dried up and turned into dry land. Vast deltas are built up at the mouths of rivers. England is said to have an area of some 300,000 acres less than at the time of the Norman Conquest, owing to the encroachments of the sea on the East coast. The Mississippi is said to deposit each year soil enough in the Gulf of Mexico to cover 268 square miles a foot deep. These are big things; but the student may and should observe the little evidences all around of the same movements. He should note how streams change their courses, cutting away a bank in one place and depositing the material in another. He should note the great gorges through which rivers and streams flow and which have been cut by their action through the ages. He should examine the composition of alluvial flats and the deposits of silt after floods. All these things will assist him in understanding the influences which have been and are at work in soil making.

The weathering of rocks. In following the effect of denudation by water and wind, we have for a time left our subject of the milling of the rocks, or, in other words, the way they are changed from hard rock to soil. In considering this subject, it is wise, as well as convenient, to deal with the more important agencies separately; but, in doing so, the student will do well to remember that system is merely an aid to study. Nature's agencies do not work singly. Nature is systematic only in broad generalities. The teacher constantly urges system in the study of

Nature; but the student of Nature finds that the system is more often created at the desk than in the field. Systematic arrangement of facts is necessary, but it is important to draw the distinction between things as arranged systematically in books and the apparent confusion seen by the student. The moral is that the student who sticks to his text-books learns the end rather than the beginning of his subject. Above all things the student is urged to use his text-book merely to help him in his actual study of nature. His opportunity for practical observation may be small; but he must use what there is to enable him to understand his book. Science is classified facts.

C. Part of the crop of Cauliflowers shown in B.

We have said that the agencies which change rocks into soil may be classed as: (1) Mechanical or physical, (2) chemical, (3) biological. These all work together, but particularly the two latter, so that chemical change is frequently the result of the work of living organisms.

Departure from old world text-books. In the explanation of mechanical or physical agencies of soil-formation in Australia, as well as in some other important matters, we have to depart somewhat from the standard English and American text-books. The agencies are the same, but their relative importance is different. For example, if we take up any of the valuable standard works dealing with soils, we cannot but be struck with the prominence given to the work of frost and glacial action in the disintegration of rocks and the production and transport of soils. The statements made are accepted on the evidence tendered; but when the Australian student seeks for local examples, he is at once lost. Of boulder clays and glacial action, with a few local exceptions, he knows and can know nothing practically. The great ice-ploughs of the books must remain mere words to him. Undoubted evidences of a glacial period have been discovered in all the States; but, although of great interest to the geologist, as a factor in the formation of soils, the student of Australian agriculture may practically ignore glacial action.

Frost as an agent in disintegration of rocks. The work of frost is of greater importance, but as a soil maker and modifier in Australia frost is quite insignificant as compared to its influence in Britain and Eastern America. In no Australian agricultural district of any importance, if at all, is the ground ever frozen. Only on the mountains of the extreme south-east of the continent and in Tasmania does the ground become annually covered with snow for any length of time, and nowhere does it exercise any important influence on Australian agriculture, except that the snow which gathers in winter on the Australian Alps melts in summer, and thus supplies water for the River Murray, which is used for irrigation. Severe frost, as understood in the text-books, is practically unknown in the larger agricultural areas of Australia. Natural ice-skating is absolutely unknown. In the coldest parts of Western Australia, South Australia, and New South Wales, also of Victoria, excepting the mountains of the south-east corner of the continent, a severe frost means nothing more than coating water-troughs and puddles, and, perhaps, ponds of water with thin ice, which seldom lasts through the day. Such frosts are considered worthy of special comment, and anything a little more severe in any locality is deemed worthy of telegraphing to the metropolitan newspapers. In Melbourne during fifty-three years the temperature of the air has never fallen below 27 degrees Fah., or 5 degrees of frost. This amount of frost has its influence, as will be shown later on, but it is not the powerful active agent to which so much prominence is given by writers on soils in Europe and America. The thought of leaving heavy land in fallow in winter to be mellowed by frost is no part of the general routine of the ordinary Australian farmer.

Variations of temperature. But although we in Australia cannot give the mechanical effects of freezing water the importance it holds in colder countries in causing the disintegration of rocks and modifying soils, we have still to consider the effect of a great range of temperature, not only during the year, but frequently within a few days. We have to remember that water is at its minimum density at 4° Cent. or 39.2° Fah. From that point it expands until it freezes, and as small quantities do frequently freeze in winter this factor must not be ignored. It would seem, however, that we must pay more attention to heat than to cold. Relatively, the variations of temperature in Australia are not noteworthy when compared with some other places, and they occur in the upper rather than the lower portion of the ordinary thermometer scale.

The Commonwealth Meteorologist, quoting General Greely, formerly Chief of the United States Weather Bureau, states that the temperature in the sun may reach 200° Fah., but the highest actual record was made on June 8th, 1882, at Pachpadre, India, 382 feet above sea level, when 196.5° Fah. was registered. The absolute highest solar reading recorded in Adelaide was 180° Fah., on the 18th January, 1882, which it will be noted was the same year as the high record in India.

He, however, states that there is considerable uncertainty in measuring direct solar heat and that the comparisons of shade temperature are more trustworthy.

The annual range of temperature is much greater in the Northern than in the Southern hemisphere, due to the extensive land areas in higher latitudes. In Siberia, on the Arctic circle, the range of air temperature during the year may be as much as 170° Fah. At St. Vincent, Minnesota, U.S.A., the shade temperature may rise to 103.2° and go as low as – 53.5° Fah., or a range of 156.7° Fah. At North Platte, Nebraska, U.S.A., the maximum was 107° and the minimum – 34.6° Fah., or a range of 141.6° Fah. Other similar figures might be given relating to some other great wheat-producing States of North America.

" There is," he says, " nothing in Australia corresponding to these great differences in air temperature." At Eucla, with thirty years' records, the highest shade temperature was 123.2° and the lowest 28.1°, or a difference of 95.1° Fah. At Adelaide, with fifty-two years' records, the range was between 116.3° and 32°, or a difference of 84.3°, while Melbourne, for about the same period, has a maximum record of 111.2° and a minimum of 27.0°, or a range of 84.2°. Sydney's maximum in forty-nine years is 108.5° and her minimum 35.9°, or a difference of 72.6° Fah., which corresponds to that of Perth, where the greatest range is between 107.9° and 35.3°, or a difference of 72.6° Fah.

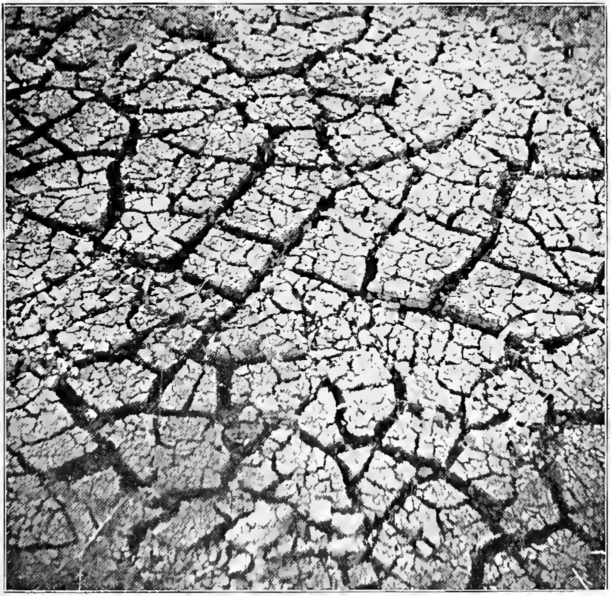
These are interesting comparisons which should be known to the student of agriculture, but, in considering the effect of temperature on the rocks and soil, we have to take into consideration the difference between the absolute solar heat, known generally as the sun heat, and the absolute minimum on the ground. When we speak of the minimum shade temperature we mean the temperature of the air at about four feet from the surface of the ground. On the grass near by the temperature may be considerably lower. Thus there may be, and often is, frost on the ground, and potatoes may suffer, when the records show that the air temperature was several degrees above freezing-point. The Commonwealth Meteorologist states that it is safe to say that the range of temperature between solar reading (that is the temperature in the sun in the day) and the lowest record on the grass at night in many places in Australia is frequently over 100° Fah. in the twenty-four hours, and at times may be up to 120° Fah.

Expansion and contraction. There is another way of looking at the range of Australian temperatures in relation to their effect on the disintegration of rocks. We know that a rock surface or a sandhill, exposed to the direct rays of the sun, absorbs heat until it is so hot that even a black fellow cannot walk on it, and camels will lie down unable to endure it. There are no records, but the temperature of sand and rock surfaces in the interior may be assumed to reach fully 200° Fah., and to fall to or below freezing-point.

We have to consider in this connection that many rocks are composed of different mineral substances, having different co-efficients of expansion, and the effect of this alternate expansion and contraction must tend to split the rocks. Mention is made of the same thing in Arizona and Texas in America, and Dr. Livingstone speaks of blocks weighing up to

200 lbs. being split off during the night in South Africa by the contraction due to a rapid fall of temperature.

The disintegrating action of great heat goes on in summer, but we must not ignore the effect of frost.



Deposit of Silt left by Winter Flood.
Showing Cracks produced by the Shrinkage on Drying.

The interior of Australia is subject to great radiation at night, and although the frosts are not severe, they are sufficient to freeze the small quantities of water in the surface cracks of the rocks caused by the heat of summer. To the two influences described may be chiefly attributed the accumulation of angular stones at the base of any rock cliff. In the case of the flaking off of the surface of granite and some other rocks of mixed composition, we must add to the above the solvent action of carbonic acid causing partial decomposition, thus affording opportunity for the action of frost.

The combined agencies of heat and cold, long dry summers and heavy rains, in causing alternating expansion and contraction resulting in the exertion of great force, exercise influence in soil formation and modification. A common practice of quarrymen may be mentioned as an example of the power exerted by the unequal expansion of different substances. To obtain regular blocks of very hard stone, rows of small shallow holes are drilled along the desired line of cleavage. Into these holes plugs of dry soft wood are driven, and these are then soaked with water, and masses of rock many tons weight are separated by this simple means. Suppose we have a big mass of rock with various joints and cleavages filled with clay in a dry state. When this is wetted the expansion exerts an enormous force. Reduce the water anything below 39.2° Fah. and further expansion takes place down to the freezing-point, when the force is immensely increased. It will assist in understanding this to remember that the expansion and contraction of clay causes the biggest buildings to crack when built on clay beds, often in spite of every precaution and great expense in foundations.

Among other mechanical influences which reduce rocks to soil must be mentioned the action of the waves on the sea beach, and the work of running water in streams and the effect of wind on exposed surfaces.

Chemical agencies of soil formation. Chemical changes in the soil are largely due to or associated with the life, growth, and decay of organisms which exist in or on the soil, but direct chemical agencies have to be considered. The most important of these is the action of carbonic acid. Most rock materials are insoluble in pure water, but water in nature is never pure. Its clearness, brightness or sparkle, and its palatability, are often merely evidences of other substances in solution. The all-important chemical agent in the disintegration of rocks into soil is carbonic acid, the action of which few rocks can resist. The prominent exception is pure quartz, the small quantities of pure silica often found in solution in water being due according to Hall to " the decomposition of natural silicates by water containing carbonic acid rather than from the direct solution of quartz."

Rain water when it reaches the ground contains some carbonic acid gas in solution, and this is increased in the soil owing to the fact that the soil contains a considerable quantity derived from the decay of vegetable matter. Hall quotes Wollny to the effect that at a depth of a little under five feet the amount of carbonic acid in the soil gases varied from 3.84 per cent. to 14.6 per cent. at different periods of the year. These figures may or may not apply to Australian conditions because the proportion of carbonic acid in soil gases varies very much, both with the proportion of organic matter in the soil and its permeability. At greater depths the proportion increases, so that quite frequently the percolating water becomes a weak solution of carbonic acid, with very considerable solvent powers. The fact that lime, magnesia and iron, are frequently found in considerable quantities in spring waters, shows that these minerals are very readily acted upon, lime being particularly attacked wherever it is present, as it is over large areas in Australia.

The cementing agent in most sandstones is either carbonate of lime or oxide or carbonate of iron. These substances, being readily acted upon by a solution of carbonic acid, it will be seen that the solvent action tends to decompose the rocks, the cementing material being carried away, leaving grains of sand to be transported by water or carried by wind.

In Western Australia, granitic rocks with frequent dykes of diorite form the basis of the country. In South Australia and Victoria, there are also considerable areas of granitic rocks, while the latter State and Tasmania also possess large extents of basaltic and other diabasic and volcanic rocks. The felspars are important constituents of granite and the other rocks mentioned. They are double silicates of alumina, with some other base such as potash, soda or lime, and one of their characteristics is the ease with which they are attacked and decomposed by the chemical agency of carbonic acid in solution. The result is that the lime, soda or potash, is removed in solution as is also some of the silica. The rock then becomes rotten as it were, as anyone may see who will observe the decomposing of these rocks. The alumina remains as a hydrated silicate and forms clay, in which are embedded grains of quartz, mica and hornblende. The pure clay washed away forms beds of kaolin or white clay, which is the material used for fire-bricks. The quartz forms sand, and mica being light, often floats away or, when decomposed, may be a source of potash. Here in a few sentences we have the explanation of the prevailing sandy soils of Western Australia and those portions of the other States where granite is the prevailing rock. We also have one factor in the explanation of the formation of the kaolin clays which, with oxide of iron as the binding material, constitutes one of the forms of "hard" pan subsoil of many localities.

The change in basaltic and diorite rocks is similar, but here the clay is red or yellow owing to the abundance of oxides of iron, which results from the decomposition of the hornblende and other minerals in these rocks. As many of the felspars contain potash, it is usual to conclude that clayey soils will be well supplied with that important plant food; but although this is generally true with respect to the red and yellow clays, it does not always follow that such is the case.

Soil full of life. The soil teems with visible and invisible life. The old conception of the soil was that it was a lifeless mass, but the microscope has shown us that soil is usually fertile in proportion to the population of favourable micro-organisms, and also that there are forms of micro-organic life which may render otherwise well-constituted soils unfit to produce profitable agricultural crops.

A fertile soil is one in which farm and garden crops grow readily when the climatic conditions are favourable. Decomposed rock, however well supplied with mineral plant food, does not in itself constitute a fertile soil, because the supply of plant food is only one of several important factors which go to make up the complex condition known as fertility. In addition to its mineral constituents, a fertile soil must contain a proper supply of humus, or organic matter in a process of active decomposition, and this necessitates an abundance of micro-organic life, a proper neutral condition involving the presence of a suitable base, the best of which is lime, with which acids may combine, suitable physical conditions, and so forth.

From rock to soil. It is interesting to consider the newly exposed face of a rocky railway-cutting and recall what happens. First the physical and chemical agencies begin to decompose the rock, but almost at once the surface supports lichens, mosses and other lowly plants, their vigour and character depending largely on the moisture conditions. In arid regions they are few, in moist climates numerous. They depend for nutriment chiefly on the atmosphere, but the weak acid solutions produced by the plants assist in dissolving small portions of mineral matter, and as they decay form, with the decomposed mineral matter, little pockets of soil in crevices. In these, larger and more highly organised plants find a home and their roots exercise a still further influence in widening the cracks and even splitting open rocks. Plants also produce leaves which fall and increase the soil pockets, and slowly the work goes on until the whole, if not too steep, becomes covered with soil.

The soils round Sydney afford a striking example of the fact that the nature of a soil depends on the rock from which it is derived, plus the vegetable matter from the decay of the plants grown in it. The rock is a white and yellow sandstone, so excellent for building purposes that it is exported to other states, but not good as a source of plant food. The soils are therefore sandy and poor. Further south, where basaltic rocks are found, the soils are correspondingly rich and fertile.

Let us suppose another condition, that of a recent flow of volcanic lava. Can anything be less inviting than such a mass of black barren rock? Those who have seen a slag heap at a big smelting works have a very good idea of the desolated, barren, black appearance of a field of lava, with its rough surface, full of cracks formed by the contraction of the material while cooling. The process of decomposition very quickly commences, the minerals are attacked by the carbonic acid in solution in rain water, lichens and lowly plants form the first organic life, dust is deposited by the wind, the crevices become filled with decomposed material, and provided the climatic conditions are favourable, higher plants obtain a footing, the seeds being carried by the wind or by birds. As will be seen later vegetation draws most of its bulk from the air and water, and its decay increases the soil material for future generations of plants. In the course of time the field of lava becomes covered with fertile soil such as is seen in parts of Victoria, the rich volcanic soils of parts of New England, etc., and Northern Tasmania.

Take another example, say a bed of volcanic ash as at Mount Gambier or Warnambool, or a railway embankment of entirely mineral material, or a deposit of washed rock debris free from organic matter deposited by a river, the sea, or wind. Here the process is more rapid owing to the fineness and nature of the materials. Seeds soon find their way to the barren spot, and, provided climatic conditions are favourable, in a comparatively short time the place is covered with vegetation, the decay of which continues to modify the surface, and in time the mass of barren mineral becomes a fertile soil.

Special plant agencies. In the making of soils mention should be made of the special work done by particular kinds of plants, a subject which will well repay the careful observation of the student. Take for example the action of plants which act as sand-binders, such as Marram grass, by which areas of drifting sand have been reclaimed at Port Fairy on the coast of Victoria, Yankilla and Goolwa in South Australia, and at Fremantle and Karridale in Western Australia. The natural herbage of coastal sandhills is largely of this character, as anyone may see who takes special notice of the sandhill spinifex, and so forth. These plants hold the sand while humus is being formed to transform it into soil, and at the same time help in supplying the humus.

In the case of swamps we see how they are covered with coarse reeds and water-plants which gradually fill them up and form deposits of peat, which only has to be drained and sweetened to form rich and productive potato and vegetable garden soil.

Animals. Animals also play an important part in soil making. To realise this one must watch the work of earth-worms and then read the record of Darwin's observations. Burrowing animals play their part, and so do the ants, burying beetles and grubs. The termites, or so-called white ants, exercise an enormous influence in many parts of Australia.

Marram Grass Planted on a Drifting Sand Hill completely Stopping the Drift.

Soil and subsoil. If the student will take notice of any new section of soil, say on a roadside cutting or a drain, he will observe that the surface soil differs in colour as well as in texture from the subsoil which is below. The surface is almost invariably darker in colour, varying from a light brown to black, and is also of a looser texture if the subsoil is clay, but denser if the subsoil is sand. These differences are almost entirely due to the organic matter which the soil contains, and its absence from the subsoil.

The student will also have noticed how the texture and colour of garden soils is changed in a few years by the use of large quantities of stable manure, and that swamp soils are almost invariably dark-coloured or quite black. If he has not previously done so he should take some of the black surface soil, spread it on a shovel, and put the shovel on a fire so that the shovel and soil will become red hot. Let it remain for a time, then allow it to cool, and the colour will have changed, as will also the character of the soil. To make the experiment complete the soil should first be well dried on the fire, then weighed, then heated as above, and then weighed. The difference will represent roughly the organic matter which has been burned out.

Humus and bacteria. The organic matter in the soil is derived almost entirely from the decay of vegetable matter. It owes its character to the work of micro-organisms in the soil known as ferments or bacteria. The substance of plants is largely carbon in various combinations, particularly with the elements of water forming carbohydrates (p. 99). Certain species of bacteria produce what we call rotting, decay, or decomposition. One group, universally distributed, live and grow in the absence of air and attack the carbon compounds of plant tissues, especially the carbohydrates. By their life-work they break up the organic tissues and produce compounds, hydrogen and carbon (marsh gas), carbonic acid and peaty material. These bacteria are known as anaerobic.

Another group of soil ferments, called aerobic bacteria, live and work in the presence of air, and the result of their action is the complete combustion or destruction of organic matter, the chief product being carbonic acid.

It is important to remember these two groups of soil ferments, for it enables us to understand why peaty material accumulates in swamps which are water-logged most of the time, and why draining the soil, good tillage, and the addition of carbonate of lime, lead to the loss of organic matter, rendering it necessary to replace it with stable manure or the ploughing in of green crops, grass, etc. It also explains why humus accumulates more in pasture land than in tilled land, and why draining swamp lands is necessary to permit the working of the aerobic bacteria which are always associated with fertile soils. Acid soil conditions are unfavourable to the life of aerobic bacteria, so essential to fertility, and this is remedied in agricultural practice by drainage, soil aeration, the application of carbonate of lime. The composition of humus is not clearly understood, but the student will find as much as is known explained in Hall's work on Soils. One point must be noted, and that is the fact that in the breaking down of humus by soil bacteria, nitrates and other available plant foods are formed, so that soils well supplied with humus are generally fertile.

CLASSIFICATION OF SOILS.

THE common terms used in connection with the description of soils are familiar to all. Thus we speak of a clay soil, sandy soil, loamy soil, peaty soil, mellow soil, a sandy loam, a loamy clay, and so forth. The use of these terms fairly well conveys the general idea of what is meant, but the meaning is not exact, nor can it be so, because all such expressions are merely relative or comparative in their meaning. It would not be worth while devoting much attention to the consideration of these terms, were it not that doing so enables us to discuss the nature of soil, its composition, and the influence which composition has on physical character.

We must ever bear in mind that exactness of definition is not possible in connection with a substance of such a complex nature as a fertile soil. If it were possible to examine a mass of it in such a way that we could see what was going on, we should note that water, carbonic acid, and heat are acting on it, organisms are constantly at work in it destroying some substances in the making of others, and in the process changing its chemical composition, its physical character, and its agricultural value. The particles of rock may be worn smaller each year, or the tiny grains may be gathered into little groups or aggregations, and the plant foods are changed from one form to another. The soil has a flora and a fauna of its own, scarcely less complex than that with which we are familiar on its surface. The labour of the farmer is directed to assist some and check others of these processes, and the more he knows of them the better is he able to accomplish his purpose.

The texture of a soil depends chiefly upon the proportions in which the particles of various sizes are mixed together. Other modifying influences are the amount of humus in the soil, and the influence of such ingredients as lime and iron oxide. The humus tends to make a sandy soil more firm and clay more porous. The presence of carbonate of lime acts in a similar beneficial way, while oxide of iron may cause the binding of a soil into a hard mass.

Sand. Sand consists chiefly of grains of quartz, sometimes angular, sometimes more or less rounded by continual rubbing, the latter being a distinctive feature of sand on the seashore. The colour may vary, chiefly owing to the presence of oxide of iron. Sand represents the quartz contained in the original rocks, weathered and worn by the various agencies which cause their decay. On examining sand closely, however, it is found to contain other things besides pure quartz grains. Near the seashore there will frequently be seen small particles of shells, and almost everywhere there are present fragments of many of the minerals originally associated with the quartz from which the sand has been derived. Flakes of mica are common, as are also more or less altered grains of felspar and oxide of iron, while in cases, tinstone, or oxide of tin, is present, and in other places there are considerable deposits of what is called ruby or garnet sand, almost entirely composed of grains of worn garnet crystals. As a rule the finer the sand the more numerous are the particles of minerals other than quartz. The chief characteristic of sand is its want of coherence when dry, and the readiness with which water percolates through it. Sand makes poor soil, its want of fertility being chiefly due to the size of the particles and the character of the materials of which it is formed.

Clay. The opposite of sand is clay. Its distinguishing feature is the fact that it can be moulded and worked into various shapes, and it will retain these shapes on drying. During the drying process, however, a shrinkage takes place, but the dry material is hard and tenacious, and, unlike sand, can only be broken or crumbled with difficulty. In a moist condition it is impermeable to water, and for this reason it is used to line the bottoms of dams and tanks in porous soil, and a wall of it is usually built up inside the retaining wall of large dams or reservoirs. Quite a thin layer of clay will hold water as long as it remains moist, but if it is allowed to dry the shrinkage may be as much as five per cent., cracks and fissures are formed, and it is not until the clay again swells and closes these that it once more becomes water-tight. Those who are familiar with buildings erected on clay beds, as in Adelaide for example, are aware of the great shrinkage caused in clay drying, and the frequent cracks in houses erected on clay are evidence of the immense power exerted in the process. A. D. Hall in his book on Soils says, " The characteristic properties of clay are not developed except in material, the particles of which are less than one five-hundredth part of a millimetre in diameter." Clays are largely derived from the weathering of felspar in granite and diabasic rocks, and consist largely of a mineral called kaolinite, or more commonly kaolin, which is the hydrated silicate of alumina. The finest of all clays, called china clay, is this mineral almost pure, and the more common pipe-clays and fire-clays, from which fire-bricks are made, are less pure forms. These clays, though valuable in the industries are, from an agricultural point of view, poor and may be positively harmful, especially when they form impervious hard-pan subsoils. Ordinary clays vary in character as well as in composition. According to their nature and origin they may be rich or poor in plant food. The nature of clay subsoils is of great importance, and in no case more so than in apple growing. Ordinary fertile clays vary from various shades of yellow to red, and this colouration is due to oxides of iron. Ordinary clays also usually, but not necessarily, contain fair percentages of potash, as well as fine grains of quartz, mica, and other weathered minerals.

" Colloid " clay. People in Australia, particularly in the agricultural districts, are thoroughly familiar with the fact that when water is collected in a dam or tank from clayey ground the clay is often so fine that it does not settle, and the water appears discoloured and slightly muddy unless specially treated. When clay possesses this "colloid" character, it is due to the extreme fineness of the particles, but when a solution of a substance such as chloride of iron, alum or of lime be mixed with it, it causes the very fine particles of clay to "flocculate," that is to collect together into grains heavy enough to quickly settle, leaving the water clear. Rothera (*Victorian Journal of Agriculture*, July, 1910) has demonstrated that 1 lb. of ferric chloride will clarify 1000 to 2500 gallons of muddy water, 1 lb. of alum 500 to 1000 gallons, and lime about one-fourth as much. The fact that some substances have the power of causing the fine particles of clay to unite in larger aggregations, is of some considerable importance in connection with practical agriculture, because on it depends the value of humus and lime in modifying the mechanical texture of clay soil. If a portion of pure dry clay be taken and divided into two portions, one being kneaded into a solid lump with pure water, and the other similarly treated with lime water, it will be found on drying the lumps that the one made with the lime water will shrink and crack less than the one made with pure water, but it will more easily crumble into a powder.

Although the figures are too large to be grasped it is of interest to state that the methods of mechanical soil analysis enable the analyst to approximately distinguish the character of soils by the number of particles per cubic centimetre or cubic inch. Thus, what the American calls a good corn or maize soil, is stated by Fletcher to contain 280 thousand million particles to the ounce, while the clay loams that are preferred for grass often have 400 thousand million particles to an ounce.

The relation of fineness to richness. The fineness of a soil has a very important bearing upon its fertility, because a given volume of small soil particles will have a greater total extent of surface on which the roots may feed than will the same volume of coarse soil; but if the particles are too small, the soil is too compact for the free action of the root hairs. This, however, is only one of the several factors, as will be seen later. Water is the all important substance obtained from the soil by the roots of plants; but with this water they obtain their nitrogen and all mineral plant food in solution. Fertility may be said to be to a considerable extent a matter of water-holding capacity, and this, apart from the humus content, is very largely in proportion to the fineness of the particles of the soil. Here again it must be repeated that no one factor can be considered alone.

In discussing this matter we may proceed by considering in turn the weight of soil, pore space, capacity of soils for holding water, how the water is held, percolation and drainage.

The weight of soils. The weight of a cubic foot of soil depends upon its composition and compactness and is often an indication of the percentage of humus it contains. Therefore, to a certain extent, weight is an indication of its value for agricultural purposes, but we must not overlook the important fact that when a farmer speaks of a heavy or a light soil he refers to texture, not weight. He speaks of a clay soil which is difficult to work as heavy, and of a sandy soil, easy to cultivate, as light. Judged by weight per cubic foot the sandy soil is the heavier of the two, and coarse sharp river sand is heavier than fine sea sand.

Speaking generally the coarser the soil grains the greater the weight per cubic foot. Usually also the higher the percentage of humus the lighter the weight of a given volume. The weight of a soil always refers to the dry condition, *i.e.* to the soil when all free water has been expelled by heating it to slightly above the boiling-point of water. A sample of peaty soil when dry is "as light as a sponge," but when saturated it may be compared to the sponge full of water. The following comparative weights of a given volume of dry soil are from Schubler:

Sand,	100 lbs.
Garden soil, rich in humus,	70 lbs.
Peat soil,	30 lbs.

Hall gives the following results of determinations, made in the laboratory, of soils in a roughly powdered state and without the stones. The terms used to describe the soils are not and cannot be definite, but the figures are instructive because they show the relative differences in weight of the various classes of soils:

	Weight per cubic foot.	Lbs. per acre 9 in. deep.
Sandy peat,	49 lbs.	1,580,000
Heavy clay,	66.4 lbs.	2,154,000
Light loam,	76.4 lbs.	2,480,000
Sandy loam,	76.7 lbs.	2,490,000
Light sand,	79.2 lbs.	2,560,000

THE WATER IN SOIL.

Pore space. If we take several tumblers and carefully fill them with dry coarse sand, fine sand, and powdered clay, and add water until the material is saturated, which will require some time in the case of the clay, the tumbler of clay will take the largest quantity of water. This is a simple experiment anyone can try. The spaces between the soil particles occupied by the water are known as "pore space," and it may vary from a little over 50 per cent. in the stiff clays down to 25 to 30 per cent. in the case of coarse sands of uniform texture.

The question of the water holding capacity of soils is somewhat difficult to understand on account of the different factors which have to be taken into consideration. If we consider the size of the soil grains only, we have the simple rule that the finer they are the larger the amount of water required to saturate the soil and the greater the quantity of water it will retain when all the free water has drained away. The farmer would state this fact by saying that clay takes more water to thoroughly wet it than does sand, and it holds moisture longer. At the same time he knows that in a dry season, a light sandy soil will often carry a crop better than heavy clay. The explanation is simple. In such a season there is not enough rain to saturate the clay land, and its water holding capacity is not put to the test. It is also a fact that while sandy soil will not hold as much water as clay, it will give up to the plant a larger percentage of what it does hold when saturated. We therefore have two factors operating. First, with a small rainfall, the sandy soil becomes wetter than the clay ; and second, a larger percentage of the water is available for the crop.

Decayed vegetable matter, commonly called humus, will hold more water than clay. Therefore, when a soil contains a large percentage of humus, its water holding power is greatly increased. Neither pure sand nor pure clay makes a fertile soil, and it is recognised that the proportion of organic matter which any soil contains is of the greatest importance. The water holding capacity of a soil is quite as important as the supply of plant food, and this power to hold water depends partly on the percentage of humus it contains.

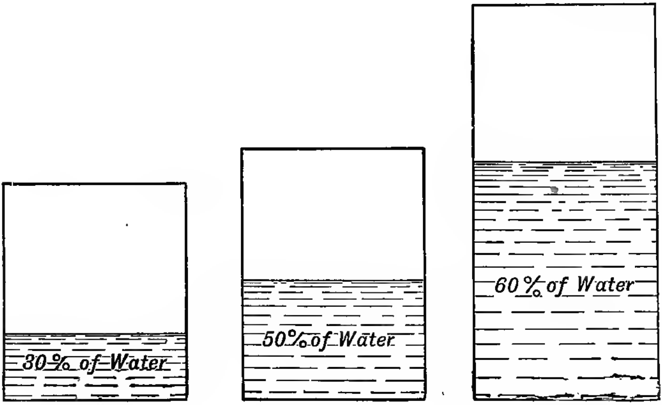
If we take given weights of different types of air dry soil, we find that they differ very much in volume. One hundred lbs. of peaty soil will occupy much more space than the same weight of sandy soil, clay coming in between.

The water content of a soil may be considered in three ways :

1. We may consider the proportion the water in a saturated soil bears to the dry soil.
2. We may take the weight of a volume of wet soil and find how much of that is water.

3. We may find the percentage by volume which the water occupies in a soil.

The following diagram is an attempt to give the student an idea first of the relative volumes of a given weight of three classes of soils, and second, their water holding capacity. The rectangles show the comparative volumes of dry soil; and the shaded portion the percentage of water in a saturated soil of that class.



Sandy Soil. Clay Soil. Soil with Large Percentage of Humus.

The quantity of water required to saturate a soil is only one of several factors in relation to the supply of water to plants. The roots of our ordinary agricultural crops cannot thrive and usually cannot live in a saturated soil; but some plants, like the swamp varieties of rice and swamp vegetation generally, require extreme wet. According to Helriegel, ordinary plants thrive best when the soil is not quite half saturated, that is, of course, when other conditions are favourable. In Australia the larger proportion of our agricultural areas is subject to more or less regular dry periods, which would be called droughts in Europe. Over millions of acres of profitable wheat and sheep-farming lands in every Australian State, the soil is rarely saturated to any considerable depth.

Hygroscopic moisture. No soil, even under the dry summer conditions of the hotter parts of Australia, is absolutely devoid of moisture. Even the fine dust on the roads of Kalgoorlie and Broken Hill contain some moisture, and we know that many plants remain alive, in a more or less dormant condition, all through the great droughts of central Australia. The water held by air dry soils is called hygroscopic moisture. It is not fully understood how it is held; but it is there, although it does not appear to be available for the use of plants. Soils have varying capacities for absorbing moisture from moist air.

Film water. King gives a good illustration of how the fineness of a soil influences the quantity of moisture it will hold. He says: "Suppose we take a marble just one inch in diameter. It will just slip inside a cube an inch on a side and will hold a film of water on its surface 3.1416 square inches in area. But reduce the diameter of the marble to one-tenth of an inch and at least 1000 of them will be required to fill the inch cube, and their aggregate surface areas will be 31.416 square inches. If, however, the diameter of these spheres be reduced to one-hundredth of an inch, then 1,000,000 of them will be required to make a cubic inch, and their total surface area will be 314.16 square inches. Suppose again the said particles have a diameter of one-thousandth of an inch, it will then require 1,000,000,000 of them to completely fill the cubic inch, while their aggregate surface area will measure 3141.59 square inches."

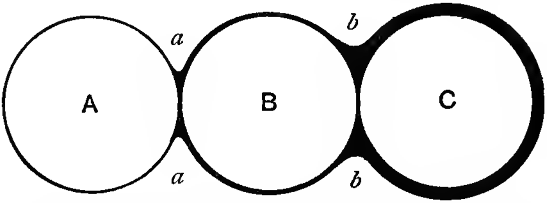
He shows that these particles are quite large as compared to those of a fine soil, yet a cubic foot of them will hold a surface film of water equal to 37,700 square feet. Roots of wheat go to a depth of at least four feet, so that the available surface of the particles of soil below each square foot of moist ground would possess a water film of not less than 3.4 acres.

It is from this film water, covering the soil grains, that the root hairs of plants obtain their supplies, and the student will see how it is that our wheat crops are produced on so small a rainfall coming at the right time, with none running away, and how important it is where the rainfall is light to get it all into the soil and keep it there by surface cultivation to provide a soil mulch.

The film of water on the soil grains becomes gradually thinner as the soil dries until the air dry stage is reached, when only hygroscopic moisture is left.

Capillarity. The moisture in non-saturated soil forms an elastic film over the surface of each grain and between the grains in contact, being held by a force which binds it to the grain and is always tending to keep the thickness of the film constant. Thus, when any moisture is drawn from one part of a soil grain the remainder attempts to adjust itself evenly over the whole surface. Similarly, when moisture is taken from one grain, that from all the adjacent grains in contact is redistributed so that the moisture in any mass of soil tends to be uniform. This is really what is known as capillarity, so frequently referred to by writers on agriculture. It operates in every direction. When the sun draws off water from the surface particles, there is an upward movement to adjust the difference.

Hall illustrates the movement of film water in this way:



A, B and C represent three soil particles, of which A and B are surrounded by thin films and C by a thicker film of water. When the spheres are in contact, the water will fill up a part of the angle between the spheres, as shown in the diagram; but the water surface at *a* is more curved than at *b*, and by the law of capillarity the pressure at *a* will be lower than at *b* and there will be a flow of water from *b* to *a*, and this will continue until the curvatures and corresponding surface tensions are equalised.

THE TEMPERATURE OF SOILS.

THE relation of the temperature of soils to the growth of vegetation is important in Australia, as elsewhere, but the problem here has some features differing from English and American conditions. We have not the same degree of cold, but we have to contend in many places with intense heat acting on very dry soil. In England and Eastern America, the soil rarely becomes too warm for summer farm crops, and, provided the moisture content is right, the same may be said of New Zealand, Tasmania, and the cooler districts of the mainland ; but over large areas of every State of Australia the summer heat of the soil is altogether too great, combined with the lack of moisture, for any but specially adapted plants. At the same time, it is often too cold in winter for rapid growth, and it is important, on account of the short spring and dry summer, to endeavour to do all that is possible to make the soil warmer in winter and cooler in early summer in order to extend the growing period of crops.

It is only when the soil has reached a temperature of from 65° to 70° Fah. that most crops grow freely, so that even in districts which are so hot and dry in summer that agricultural plants will not thrive without irrigation, the crops and pastures make little headway in July.

It is well known that seeds germinate more quickly and better when the soil is warm than when it is cold, and that certain seeds, like tomatoes, melons and so forth, will lie in the ground all through the winter and only germinate in September or October, when the soil becomes sufficiently warm. There is, indeed, a minimum and a maximum, below and above which each kind of seed refuses to germinate. This is well seen in the case of weeds which appear at regular times, either in spring, summer, autumn or winter, according to their nature. Our gardens may be full of seed of various weeds, but all our watering in the summer will not start certain kinds to grow until the days shorten and the soil becomes cooler in autumn.

TEMPERATURES (FAH.) OF GERMINATION (FROM HALL).

Crop.	Minimum.	Optimum.	Maximum.
Wheat, - -	32 to 41	77 to 88	88 to 110
Barley, -	40	77 to 88	100 to 110
Oats, -	32 to 41	77 to 88	88 to 100
Pea, -	38 to 41	77 to 88	88 to 100
Scarlet runner bean,	49	91	115
Maize, -	49	91	115
Cucumber, melon, etc.,	60 to 65	88 to 90	110 to 120

These temperatures practically apply to the growth of the same plants, *i.e.* the most favourable temperature for germination is the most favourable for growth. Although farmers and gardeners may not know anything about the law they practically apply it. The gardener makes a hot bed for his early tomatoes, cucumbers and melon plants; he raises his beds and sometimes gives them a northern slope when growing winter salads, and he knows quite well that there is usually nothing gained by sowing his melon seeds too early in the spring, unless he adopts means for raising the soil temperature.

The farmer knows from experience that he gets poor results from sowing lucerne, maize, and such crops too early, because not only does he run the risk of losing his seed, but, if it germinates, the seedling plants make poor growth until the soil warms, and being weakly they are liable to the attack of insects and diseases. The Tasmanian potato grower produces his crop in summer, but on the Adelaide plains the potato is an autumn or early spring crop. Similar examples might be multiplied indefinitely.

Temperature and soil bacteria. There is another important factor to be considered. The supply of some forms of available plant food in the soil depends largely on the work of soil bacteria. This applies specially to the breaking down of organic compounds of nitrogen into nitrates. These bacteria are active between the temperatures of 41° and 130° Fah. Here is the probable explanation of the fact that in our Australian wheat areas nitrogenous manures as a rule fail to give the results found elsewhere. The matter has not been carefully investigated, but the soil temperature, during a considerable period of the year, is most favourable to the work of the nitrifying bacteria and when the soil moisture is conserved by fallow, soil bacteria provide sufficient of this, the most essential and costly of plant foods. The explanation is rendered the more probable by the fact that top-dressing crops with nitrates or ammonia at the end of the winter, in cool wet districts, seldom fails to give good results. Under such conditions winter rains wash out the soluble nitrates produced during the previous summer, and the soil temperature is not favourable for the bacteria to provide a fresh supply of this essential plant food as quickly as is required by the crops. This point is of importance in connection with the early sowing of cereal crops.

Factors in soil temperature. The factors determining soil temperature are varied and complex. The main source of soil warmth is the sun's rays, and is therefore beyond the power of the farmer to influence one way or another. He cannot make the June and July days longer or give the oblique rays more warming power. He cannot modify the intensity of the summer sun or lessen the water absorbing powers of the hot winds from the dry interior of the continent during a heat wave. He can, however, to some extent modify the effect of the natural conditions under which he works, and a knowledge of the principles governing soil temperature will at times guide him in his work.

At a depth of thirty feet or so the soil temperature changes very little through the year. At the Auldana Wine Cellars, Magill, South Australia, the temperature in the vaults in the hill, fifty feet from the surface, varies between 60° and 62° Fah. from winter to summer. The similar vaults thirty odd feet underground at the Great Western Vineyard, Victoria, remain almost equally constant in temperature.

Effect of colour on temperature. The temperature of the surface soil varies very much from season to season, from day to day, and from day to night. The daily fluctuation, however, rarely extends more than thirty inches down. The colour of soils influences their temperature considerably, because the ordinary laws of absorption and radiation apply to soils. With black soils the absorption of the sun's rays is almost complete, red soil absorbs more heat, and becomes warm more quickly than yellow and light coloured soils, and lose heat with corresponding rapidity, other factors, of course, being equal, which is usually not the case. In Switzerland farmers sometimes strew black powdered slate over the snow to hasten its melting.

Gardeners in cold countries sprinkle a light coloured soil with peat or charcoal to warm it. In Saxony, melons are ripened by covering the soil with a layer of coal dust. Humus darkens a sandy soil and warms it. The dark soil also absorbs more heat during the day and gives it off at night, thus warming the air immediately above. Covering a soil with white powder, such as air slaked lime, on the other hand, reduces the soil temperature and retards a crop.

Other factors. The coarser the particles of a soil the warmer it gets and the better it holds the heat, and, in accordance with this fact, gravelly, sandy, and sandy loams, especially when dark coloured, are known to be among the earliest and warmest of soils, and are often so described. In Europe, gardeners sometimes cover the ground under vines with gravel to increase the temperature and hasten the maturity of the grapes, and the raisin drying grounds of Spain, in addition to being usually chosen or made to slope towards the sun, are covered with dark gravel.

In apparent partial contradiction to the last paragraph, it must be noted that soils in which the particles are very small, as in clay, warm faster than sand because the grains lie so close together that the heat passes from one to the other readily. For the same reason a mass of stone will more quickly become hot than a similar volume of earth, especially loose earth.

Clay soils are often dark in colour, so that two factors, colour and fineness, operate together in absorbing heat rapidly, and yet it is a fact that sandy soils are "warm" and clay soils are "cold," because other influences have to be considered.

The mention of two factors will harmonise the apparent contradiction. The first is that clay soils lose heat as quickly as they absorb it, and for the same reason. The second is that clay soils hold more water than sandy soils, and this acts on the temperature in two ways. First, it takes much more heat to raise a pound of water one degree in temperature than it does to correspondingly warm a pound of soil; therefore, soils which are naturally retentive of moisture take a corresponding amount of heat to warm them, and are cold and late. Second, the evaporation of water from wet soils absorbs a large amount of heat in the process, and this lowers the temperature. Wing states that the evaporation of one pound of water from a cubic foot of moist soil may reduce its temperature 10° Fah.

The tilling of the surface of a soil by bringing it into a loose condition, keeps the surface warm by reducing the evaporation, and also by rendering it a less good conductor of heat, thus preventing the absorption of heat by the subsoil. In each case conflicting factors are found in operation.

Specific heat. It is necessary here to refer to the specific heat or the thermal capacity of different soils. Different substances require varying amounts of heat to raise their temperatures one degree; or, stated in another way, some substances get hot more quickly than others under the same conditions; while others absorb heat much more slowly, but retain their heat longer. Mercury heats very quickly and cools just as rapidly, and so is used in thermometers to register changes of temperature. We must not confuse intensity of heat with quantity of heat. A red-hot wire is as hot as a red-hot anvil, although one may require ten thousand times more heat than the other to make it red-hot. A pint of boiling water is as hot as a hundred gallons at the boiling point; but the hundred gallons requires eight hundred times as much heat to make it boil. The heat which a substance absorbs in being heated is specific heat. Of all substances water has the highest specific heat, or, in other words, it takes a greater quantity of heat to raise one pound of water one degree than any other substance. The heat which raises a pound of water from 0° to 212° Fah. will raise a pound of iron to about 1900°

Fah., or a bright red heat. This difference in specific heat is of great importance in agriculture, for it explains many facts connected with soil temperature, drainage, conditions of frost, the disintegration of rocks, etc.

Effect of drainage on soil temperature. Draining a soil warms it, by reducing the percentage of water it holds, thus reducing the specific heat. King states that while it requires 100 units of heat to raise 100 lbs. of water one degree Fah., it only takes a fraction over 19 units to warm the same weight of dry sand one degree. It takes about 22½ units to do the same for 100 lbs. of clay; but it requires over 44 units to warm 100 lbs. of dry humus one degree. While equal weights of water, humus, clay and sand may receive the same amount of heat from the sun, the sand will be the warmest and the water the coolest. Here, again, conflicting factors are at work. For example, 100 lbs. of humus may occupy, say, twice the volume of the same weight of sand and the greater amount of heat it will therefore receive from the sun will tend to equalise the temperature. The dominating factor is the specific heat.

With wet sand, clay and humus, the conditions are altered. A cubic foot of dry sand is heavier than a cubic foot of clay or humus, but peat or humus holds more water than clay, and clay more than sand. But this is not all. While 100 units of heat will raise one pound of water 100° Fah. in temperature, it takes, again quoting King, 966.6 heat units to evaporate 1 lb. of water from the soil; and if this were drawn directly from a cubic foot of saturated clay it would lower its temperature over 10° Fah.

It is, therefore, evident that to drain the excess of water rapidly from a soil, instead of allowing it to remain until it has had time to evaporate, must be a great assistance in raising the temperature. The difference in temperature between a well-drained and undrained loam may be as great as from 7° to 10° Fah.

The influence of soil water on naturally moist and on irrigated lands during very hot summer weather tends to keep them cool. Watering a garden bed on a hot day helps the plants not only by supplying moisture, but by cooling the soil as the water is evaporated it reduces it to a temperature more favourable to growth.

Aspect. The lay of land, or, in other words, its slope in relation to the sun's rays, is another factor influencing the temperature of a soil, and often exercises an important influence in connection with crops. Sometimes the slope of a piece of land to the north will, with other factors, make it particularly suited for early crops. Sometimes a slope to the south will, in a corresponding way, render another field specially fitted for a late crop.

Tillage. Tillage also exercises an influence on soil temperature. The subject is a complicated one, but it may be generally stated that tillage prevents evaporation, and thus saves the heat in the soil as well as the moisture. Soil for early crops should be ploughed early and cultivated often.

The use of stable manure and the ploughing-in of green crops and vegetable matter of any kind tends to warm soils, because the fermentation and decay of the organic matter is equivalent to so much combustion.

Warm rains also affect the temperature of soils favourably in spring, because the specific heat of rain being higher than of soil, the effect of even a small quantity of water is to warm the soil.

Soil ventilation. The spaces between the grains of a dry soil are filled with air, those of a saturated soil with water. Fertile soils must contain both air and water. Soil air contains a larger percentage of carbonic acid gas and ammonia gas but less oxygen than the free air above, the excess being produced by the decomposition of organic matter.

The roots of all farm crops require a well ventilated soil, and if the soil pores are filled with water the plants will die, the plants are in fact drowned. The result of a long flood in an orange-grove is well known, as is also the effect of a water-logged soil on a wheat or other crop. Deciduous trees and vines will bear and even benefit by the saturation of the soil for a short time by a winter flood when they are dormant, but they also are killed by water lying on the land for a length of time. Moving water carries air with it and has not the same destructive effect.

Not only is air actually necessary to the roots of plants, but it is also essential, in order that the useful micro-organisms of the soil may do their work in rendering the store of plant food in the soil available.

How the ventilation of soil is improved. Under-drainage is an important factor in improving soil ventilation, and although is is not practicable in many cases at the present stage of Australian agriculture, nor is it necessary in our great wheat areas, it is of much greater importance in connection with dealing effectively with the wetter mixed farming lands in every State than is usually recognised. Under-drains not only remove the excess of water quickly and lower the water table, but they provide a system of underground passages for the free circulation of air. In wet weather the passage of the air follows the flow of water, and in the dry seasons the air may pass from the drains upwards. Drainage requires much greater attention in Australia than is usually given to it. All tillage operations, by opening the soil, promote aeration or ventilation. This is one of the values of subsoiling. Ploughing-in green crops and farmyard manure, by opening the soil, promotes ventilation. Earth worms and ants have a beneficial effect in the same way. Deep rooted plants open the soil and deepen the available area for less hardy plants. It is probable that in this connection the very objectionable stinkwort weed has done some considerable good in South Australia. It is a bad pest and useless as a fodder, but tens of thousands of acres of land have been modified by its deep strong roots, which have penetrated many feet into the subsoil and in decaying have added humus and opened up channels for air and water.

SOIL BACTERIA AND THEIR USE.

We look upon the soil as so much dirt, but the black fellows, and even dogs, horses, pigs and fowls, know better. The black fellow dresses his wounds with clean dry earth, and science confirms his experience. Horses, dogs, pigs and fowls, roll in it to remove the exudations of the skin and destroy vermin. The bushman, the prospector and the way-back farmer, perspiring amid clouds of dust where water is scarce, longs for a bath; but in its absence the good wholesome soil is in a way serving the same purpose of purification. The filth of towns is quite a different thing. At the same time, fertile soil is teeming with life of its own. There are many species, some are foes but most are friends; making up for their minute size by their uncountable numbers. So small are they that a powerful microscope is required to see them. Most are classed as bacteria; but really the micro-organic life of the soil, the flora and fauna, as it is called, is as varied as the higher life on the earth's surface with which we are familiar. Every year we are learning more about these tiny organisms and their functions. and as our knowledge increases we appreciate more highly the work of the micro-biologists who are giving us new conceptions of the principles of soil treatment. The modern farmer is working in the dark, without at least a general idea of the nature and functions of the hidden friends and foes in the soil. At the same time he must remember that the science of micro-biology is very new, and a good deal of the accepted belief on the work of soil bacteria is subject to revision.

For the proper understanding of common farm practice it is necessary to consider at least three classes of bacterial life:

1. **Nitrogen fixing bacteria of legumes.** It has been known from the earliest historic times that leguminous crops, such as clovers, peas, beans, etc., enrich the soil, and that other crops, such as wheat, thrive better after a leguminous crop. Many theories were propounded to explain the reason. The now accepted explanation was published by Hellriegel and Wilfarth in 1886. They showed that when such plants as wheat, cabbage, and so forth, were grown in sand and fed with nutrient solutions, the growth was in proportion to the amount of combined nitrogen supplied; and, if this was absent, nitrogen starvation set in as soon as the store in the seed was exhausted. Peas, beans or other legumes, grown under the same conditions, were observed to sometimes recover and begin a vigorous growth which lasted until maturity, although no combined nitrogen was supplied.

In all such cases the roots of the plants were found to be furnished with the little nodules, long known to be characteristic of the roots of legumes when grown under natural conditions. The clue was followed and legumes were grown in sterile sand supplied with other plant foods, but no nitrogen, and as soon as the stage of nitrogen starvation was reached a watery extract of ordinary soil was added to some and not to others. Those so treated recovered from the nitrogen starvation and grew to maturity, assimilating considerable quantities of nitrogen. The recovery and development was always found to be associated with the nodules on the roots, and the nodules were always found to be full of bacteria, to which the name of *B. radicicola* has been given. They could only be produced by infection from a cultivated soil or by an extract of the crushed nodules.

Then followed a controversy on the subject, but further research showed the absolute correctness of the above statements and also that if legumes are grown in closed vessels, the air of which is analysed before and after growth, the actual amount of nitrogen gained by the plant during its growth corresponds with that lost from the air. The conclusion that was reached, and is now accepted as a fact, is that leguminous plants can obtain and fix free nitrogen from the air in the soil by the aid of the bacteria living in the root nodules. The manner in which it is done is not clearly understood, if known at all, but it is generally supposed that the bacteria obtain the carbohydrates required for their life functions from the plants with which they are associated, and in return supply higher plants with available nitrogen. This association of two forms of life with dependence, the one on the other, is called symbiosis.

It was first supposed that each species of legume has it own special species of nitrogen fixing bacteria. That is now believed to be incorrect, but the practical position is not greatly affected, because although there may be but one species, it is believed to become so modified by growing in symbiosis with the different leguminous plants, that the best results are only obtained when each species is directly infected from nodules taken from the same kind of plant.

Following the discovery of Hellriegel, the Germans introduced special cultures of nitrogen fixing bacteria under the name of nitragin; and in the nineties much was expected of this "waistcoat pocket" fertiliser, but the results were not up to expectations. Other methods of preparing nitro-bacteria cultures have in turn proved unreliable under field conditions. Sterilise the soil, however, and have the culture fresh and active and the results are often remarkable.

Nitrogen fixing bacteria in Australia. The results of experiments with artificial inoculation in the various States have, as a rule, been even of a more negative character than in Europe or America. On the other hand, every kind of leguminous crop suitable to the climate seems to grow freely all over Australia and to develop a profusion of nodules. In Australia, there is seldom the trouble often experienced in England and America in establishing lucerne, for example, in districts hundreds of miles from the nearest plant. There is no record, as far as the writer knows, of anyone finding it necessary to inoculate a field with soil from an old lucerne plot. Introduced annual clovers and trefoils have spread over the whole of the settled districts in all the States. Peas grow almost wherever planted under suitable climatic and soil conditions, and produce nodules in abundance.

The writer has for some years thought that there is a relation between this fact and the large variety of widely distributed species of indigenous leguminous plants in Australia. The native Australian flora is particularly rich in genera and species of the order *Leguminosae*. He has dug up the roots of various legumes in virgin soil in unsettled districts in Western Australia, and found them so thickly furnished with nodules as to be almost like bunches of young grapes. This point is worthy of careful study, as is also the fact that in some of the dry parts of Western Australia well-water is often charged with nitrates. The fact was recorded by Mr. A. E. Mann, Government Analyst in 1905, and it has been confirmed by analyses made by the Department of Mines. It is perhaps only a coincidence that this occurs in districts where the mulga acacia scrub is the dominant vegetation, but it is not recorded in eucalyptus forest country.

2. **Bacteria of nitrification, or the nitric acid ferment.** The most important compounds of nitrogen of use to plants, excepting the legumes, are the nitrates which, as natural soil products, are the result of the decomposition or oxidisation of organic compounds of nitrogen. The process of nitrification is

due to micro-organisms and consists of two stages, each produced by distinct organisms. The first stage is the production of nitrites, which in turn change into nitrates. For this work the following conditions are necessary. The presence of nitrifying bacteria in sufficient abundance, a suitable temperature, the most favourable being 98° Fah. (the minimum is 41° Fah. and the maximum 131° Fah.), sufficient but not too much moisture, free aeration of the soil, to supply the oxygen necessary, and a base to neutralise the acids simultaneously produced. It will at once be noted that the above conditions are, to a very large degree, fulfilled in a fallow field in our wheat areas, and in our well-tilled orchards in summer. The value of carbonate of lime in the soil to act as a base will also be seen.

3. **Denitrification.** If the nitrates produced by the nitrifying bacteria are not used or washed away they may be attacked by organisms which carry the changes further, the result being the loss of the nitrogen.

Tillage and soil nitrogen. There are many points not yet understood in connection with the fixation of atmospheric nitrogen in the soil, and the rendering of the organic compounds of nitrogen in the soil available for plants, but enough is known to make the following statements:

1. The fixing of atmospheric nitrogen and the change of organic matter into compounds of such character that the nitrogen becomes available for plants, is almost, if not entirely, due to the action of bacteria.

2. Not one but many species of bacteria are involved in the various processes. One kind, of which there are many variations, work in connection with the leguminous plants, dwell in the nodules of their roots and use the carbohydrates formed by the legumes for their sustenance, and in return fix the atmospheric nitrogen which is present in the soil and render it available for their host plants.
3. It is now accepted as definitely proved that certain bacteria, of which the best known and probably the most effective is named *Azotobacter chroococcum*, are capable of fixing free atmospheric nitrogen without association with any host plant. To do this it is necessary that they have a supply of some carbohydrate, which they oxidise to carbon dioxide and water, and in the process accumulate nitrogen in the soil.
4. To be of use to the plants, organic compounds of nitrogen are usually, but not always, oxidised to nitrates.
5. Several species of bacteria cause the decomposition of animal and vegetable substances, carrying on the work in different stages until, from the organic compounds, nitric acid is formed, which is seized by lime and other bases in the soil, forming nitrates, which are the most available form of nitrogenous plant food.
6. For the work of all these useful bacteria certain conditions of the soil are favourable or even

necessary. The bacteria under notice must have a plentiful supply of oxygen. Therefore, good tillage is necessary to keep the soil well aerated. They must have sufficient moisture, light, and warmth, and here again the value of tillage is of the utmost importance.

7. The valuable species of bacteria concerned in the production of available nitrogen live chiefly, if not altogether, in the upper layers of soil, to a depth where light, air, and warmth penetrate easily and abundantly. The most favourable conditions for their development are found in what is known as mellow soil. Again we see the importance of tillage and drainage.
8. There are species of bacteria which counteract the work of those which are friendly to the farmer. These work in water-logged soils, in acid soils, and chiefly under conditions which are unfavourable for good growth of crops. Therefore, while good tillage and drainage promote the work of friendly bacteria, the absence of drainage and bad tillage promote the work of those which cause the loss of nitrogen.
9. In order that the bacteria may work successfully soils must either be neutral or slightly alkaline in their character, and there must be a sufficient supply of some base with which the nitric acid may combine to form nitrates. The best of all materials for this purpose is carbonate of lime. Therefore the farmer, and

particularly the gardener, should see to it that his land contains a sufficient supply of carbonate of lime for the purpose described.

10. Organic manures, such as stable manure, fowl manure and green manure, should not be ploughed in to too great a depth. Six inches is ample, because at that depth the conditions above named for the working of useful bacteria are most likely to be found. It is best to apply these manures in winter, when the stores of available nitrogen are at their lowest point. Nitrate of soda or sulphate of ammonia should not be applied with fresh organic manures.
11. Nitrates are soluble, and if not used may be leached out of the soil during the rainy season. They are best applied when the crop is growing.

Effect of heat on soil. In the wheat areas of Australia the most we can say at present is that the available supply of nitrogen, under the fallow system, is so ample that the application of such fertilisers as nitrate of soda and sulphate of ammonia, as a rule, prove useless, and sometimes actually lower the yield of wheat. Why this is so is only surmised. Very little biological soil investigation has been carried out in Australia. The conditions are generally considered to be highly favourable to the work of nitrifying bacteria and to the activity of the azotobacter,, which oxidise carbohydrates and fix atmospheric nitrogen, and this is the explanation generally given.

The discoveries of Drs. E. J. Russel and H. B. Hutchison, of Rothamsted, announced in the *Journal of Agricultural Science* for October, 1909, suggests another line of thought. It has been known for a long time that partially sterilising soil increases its fertility. Nurserymen and gardeners first adopted the practice of heating soil intended for the growing of seedlings, in order to destroy the seeds of weeds and various soil pests. Besides accomplishing the purpose intended, it was found that the fertility of the soil was very greatly increased. Drs. Russel and Hutchison made a lengthy and careful study in order to find the reason. Biological examination of the soil showed that the sterilisation was not complete. It was found that subjecting soil to a moist temperature of from 130° to 140° Fah. completely destroyed various classes of soil life, and only reduced or did not affect others. The bacteria which produced ammonia were reduced in numbers by the process, but as soon as the ground was cooled and watered, they developed with marvellous rapidity, with a corresponding increase in the ammonia content of the soil, quite sufficient to account for the increase in fertility. The nitrifying organisms were destroyed, but it is now known that plants are able to utilise ammonia compounds without their being further broken down to nitrates, as was formerly believed to be necessary. Higher temperatures than those mentioned tend to increase fertility by gradual decomposition of the organic matter in the soil. Further investigation is in progress to determine the full effect of heat on soil. These investigations will prove of great interest to Australian farmers, who are familiar with the rank luxurious growth of wheat, oats, grass or other seed sown on soil which has been subjected to intense heat in the course of burning off timber in clearing the land for cultivation. Often the heat is so intense that practically all organic matter is burned out of the soil, and, if seeds are not sown, the patch usually remains bare of all vegetation except moss for several seasons. When sown with wheat the growth is rank, but the development of grain is often very poor. The farmer describes the result as "blighted." No completely satisfactory explanation has been given. In such cases the sterilisation must be complete, and some further cause must be sought. In preparing a wheat field, the work of the tillage implements would be sure to re-infect the soil, but this does not apply to a severely burned patch in uncultivated land.

Effect of partial sterilisation. Summed up, the two significant changes produced by partial sterilisation of the soil by heat are: (1) An increase in the amount of ammonia; (2) the cessation of the nitrifying process.

Gradually, as the investigation proceeded, it was found that in ordinary soil there are various microscopical animal organisms belonging to the protozoa family, which devour bacteria, which are classed as plants. Although these protozoa organisms are microscopical in size they are about one thousand times as large as soil bacteria. This discovery enabled the investigators to account for the rapid increase of the ammonia bacteria in the soil. Heating the soil simply destroyed the enemies of the ammonia bacteria and allowed them a free field for rapid multiplication, with corresponding increase in the ammonia which they produce. Some of the groups of useful bacteria suffer. Among these are the nitrogen fixers. The nitrifying organisms are completely exterminated; but, although nitrification is shown to be an economical process in rendering nitrogen compounds available to plants, it is not essential, and with an increase of ammonia in the soil the plant makes a corresponding rapid growth.

Soil temperatures during summer. This effect of heat on soils suggests the possibility that the temperatures reached during heat waves in the wheat districts of Australia may be sufficient to produce partial sterilisation of the soil. The data available is so scanty that the utmost caution must be exercised in stating such a hypothesis, but it suggests that careful study should be made of soil temperatures under summer conditions and their relation to soil bacteria.

The observations of the Commonwealth Meteorological Department only record the soil temperatures at depths of one foot or more below the surface, and very little data is available as to the summer temperatures reached in the upper layers of more or less dry surface soil affected by tillage.

Professor Warington, in his book on *The Physical Properties of the Soil*, states that, for the greatest amount of solar heat to reach the earth the air must not only be clear but dry. These conditions are present over our wheat areas, and we know that the surface sand of the interior becomes so hot at times that even camels lie down, being unable to bear the heat under their feet. The Commonwealth Meteorologist thinks that it is fair to assume that rock surfaces in the interior may reach anything from 160° to 200° Fah. Warington states that Sir J. F. W. Herschal sunk a thermometer four inches deep in South Africa, and observed the temperature rise to 150° Fah. A few observations made by the writer show that when the shade temperature was 91°, and the solar reading was 145° Fah., an accurate thermometer, covered half an inch with dry dark loam, read 150° Fah., and five inches below the surface 120° Fah. A careful observer found that with a shade temperature of 110° at 1 p.m. in a wheat district of Western Australia, the soil temperature at one inch was 151°, at two inches 147°, and between four and five inches 133° Fah.

It is known to many that water in an iron service pipe on the surface of the ground will become so hot that when drawn from a tap one cannot keep his hand in it. On February 16, 1911, the writer took the temperature of water as drawn from an inch pipe fully exposed to the sun on the north side of a jarrah weather board building, and found that it registered 125° Fah. It was a clear bright day, but the shade temperature at the time was only 95° Fah.

FERTILITY OF THE SOIL.

What constitutes fertility. By a fertile soil we mean one which will produce good crops with moderate care on the part of the farmer. It may not mean great richness in plant food. This point is very important in considering Australian soils. Many millions of acres of soils in the interior of the continent cannot be relied on to produce payable crops, while large areas of comparatively poor land constitute some of the most productive districts in each of the States. Fertility, or the capacity for profitable farming, is a complex thing, depending on several well recognised factors, but it is difficult to say which is the more important. The happy combination of the following conditions make a fertile land:

1. Climate, *i.e.* the regularity and the proper amount of rainfall, suitable range of temperature, the correct humidity of the atmosphere, prevailing winds, absence of severely trying conditions, such as intensely hot winds, severe frosts, gales and so forth.

2. Richness of the soil in available plant food, and in the reserves which become available with good farming.

3. Physical condition of the soil, *i.e.* ease with

which it can be worked in order to provide the most favourable conditions for root action, the supply of air and water to the roots and so forth.

The microscopic organic or bacterial life in the soil might be stated as a fourth condition, but as it depends on the factors previously stated, it will be better to confine ourselves to the three.

AN OAT CROP ON VOLCANIC SOIL, NEAR DEVONPORT, NORTHERN TASMANIA.

It would be quite easy to mention a multitude of examples where one factor is present, but its value is destroyed by the absence of the other two, and it would not be at all difficult to find striking examples in each State where two of the conditions are very favourable, but farming is unprofitable because of the absence of the third.

The maintenance of soil fertility. The building up and the maintenance of the fertility of the soil is perhaps the most important question which the practical agriculturist has to consider. It is the beginning and the end of good farming as far as the land is concerned. Indeed, there is no need for any qualification, because farming that does not end in this is merely robbing the land, or, in other words, using capital as income. Bad farming will render the richest volcanic soils of Queensland, the deep rich alluvials of the New South Wales rivers, the productive drained swamps of the Mount Lofty Ranges or the diorite soils of Northern Tasmania, at least temporarily incapable of producing profitable crops. On the other hand, good farming will yearly increase the value of even a naturally poor farm. In fact, it may be stated as a truism that, giving favourable climatic conditions, fertility is merely a question of good farming.

Giving favourable climatic conditions and the difference between starting farming on a rich soil and on a poor one, may be compared to starting a business with a good credit balance at the bank and starting without reserve capital. The credit balance is a great help to the good business man ; but it will not save the lazy man, the spendthrift, or the bad business man from failure. In the same way, a rich store of natural fertility is a big help to the good farmer, but it only encourages the poor farmer in his bad methods. Just as the energetic good business man makes headway in spite of his lack of capital, so does the good farmer build up the fertility of his farm, and after making a living and bringing up a family upon it, leaves it to his son in a better condition than he found it.

A Fine Crop of Oats, Southern Victoria.

Muck is the mother of money. If the agricultural student will let this lesson sink deep into his heart until it becomes the controlling influence in his work, he will have learned the fundamental principle of scientific farming. Many of the old farms of England, Scotland, France, Belgium and Germany, are better than ever to-day because the work of several generations of farmers has tended to build up soil fertility, and the basis of improvement is the keeping of stock, combined with good tillage and all that it embraces. "Muck is the mother of money," said an old writer on agriculture, by muck meaning the manure produced by good stock farming. Times have changed, methods have improved, artificial fertilisers have come to help; but stock are still and ever must be the essential factor in the maintenance and improvement of the fertility of the soil. Stock are part of nature's rotation. Where stock are not or cannot be kept, intense farming is practically impossible unless organic manure is brought from elsewhere. On the extensive wheat areas of Australia, intensive farming is not possible, and we have to adapt our methods to our conditions, but this does not alter the principles. The results obtained at Roseworthy Agricultural College, and on many private farms in each of the States, show clearly that even in the wheat and sheep districts much can be done which the average farmer considers impracticable.

Virgin soils. The agricultural lands of America and to a lesser degree of Australia, are on the whole less fertile to-day than they were when first settled as virgin soils, because the tendency has been and to some extent is, to treat them as mines from which a store of wealth can be taken, after which they may be deserted for new land. Every State in Australia has witnessed the same exploiting of its stored wealth. When the first settlers came the virgin soils had had nothing taken from them except by the agencies of water and wind. For countless ages they had produced vegetation which had been fed down by wild animals or had rotted on the ground. True, the black fellow had fired the country from time to time, but the mineral matter went back to the porous soil in the ashes, the animals died and decayed and comparatively little was lost. This accumulated richness tempted the pioneer to brave no small discomforts and months of peril on the ocean in miserable ships and to submit to the hardships of pioneer life.

The settler came and proceeded to draw on this accumulated credit balance of soil fertility in the shape of wool, mutton, beef, wheat and other products, and turn them into gold. Not only was no attempt made to return to the soil an equivalent of what was taken out, but the methods followed were, and at the present time are, often thoughtlessly and foolishly wasteful. The pioneer farmers absolutely wasted much of the stored wealth, and many of their successors are doing it to-day, not even giving nature a fair chance to keep up the supply. They used up the available plant food, robbed the soil of its humus, naturally deficient in most parts of Australia, quickly got the soil into bad physical condition, unnecessarily destroyed the timber in a ruthless, senseless fashion, allowed the running water to wash away the richest of the soil, and generally acted as though they neither knew nor cared anything about soil fertility or future generations. It is necessary to emphasise this, because we cannot remedy a fault of which we are not conscious.

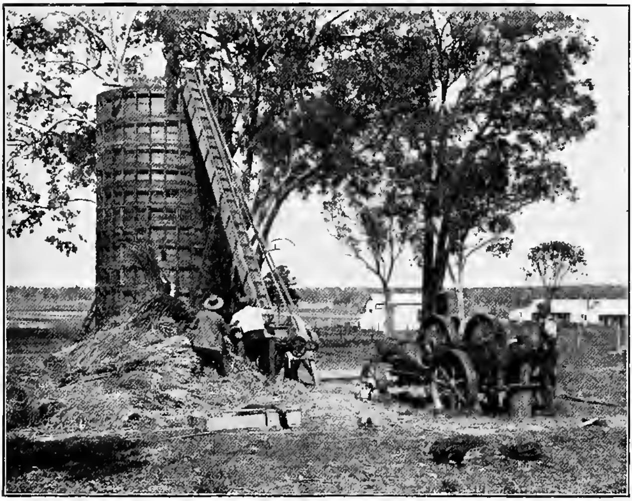
Soil is inexhaustible. Theoretically, the plant food in a well constituted soil is inexhaustible, but many soils are not well constituted. The mineral constituents of soil are derived from the decomposition of the rocks, therefore the richness of a soil depends on the character of the rocks. The process of decomposition is always going on. The humus comes from the decay of former generations of plant and animal life, and if nothing is carried away the soil grows in richness. Under natural conditions this is the case. Wind and water transport some of the material from one place to another, forming rich alluvial soils in the valleys, and carrying some to the sea, but the statement will bear the closest criticism. But while complete exhaustion even temporarily is impossible, the examples of "worn out" farms, speaking from the every-day practical point of view of profitable working, are only too common.

Pioneer policy. Whether he had had previous experience of farming or not, the object and the methods of the pioneer were practically the same. His object was to produce marketable crops which he could ship to the old world in exchange for money or its equivalent in goods. The miner exploited the deposits of minerals and shipped away gold, silver, copper, lead, etc., the pastoralist and farmer in the roughest and readiest way available, proceeded to take from the soil the accumulations of phosphoric acid, potash, nitrogen, and other plant foods, and ship them to Europe in the form of wool, wheat, hides, tallow, frozen meat, butter, wine, fruit and so forth. The fertility, represented by the products consumed by the people themselves, was and is still being equally surely withdrawn from the land, and the waste is got rid of through sewers of the cities or in villages and on farms in the readiest way available, which is usually the most wasteful manner possible, with no thought of the fact that it represents soil wealth. We are discussing the matter from an agricultural, not from the point of view of social economics, and looked at in this light, the methods are wasteful in a high degree.

Maize for Fodder to be cut for Silage.

The pastoralist and soil fertility. Grazing is usually the first use to which the lands of a new country are put, and the common belief is that this enriches rather than impoverishes the soil. Under a carefully thought out scheme of rotation on a carefully worked farm, feeding off special fodder crops and laying down land to pasture undoubtedly has this influence. Even allowing worn-out land to lay out in grass enables the soil to slowly accumulate a new store of available plant food; but this is not what we are considering. The pioneer pastoralist started with rich virgin land. His method of work was to put on as much stock as the country would carry, and harvest the annual crop of fat bullocks, sheep or wool. Every bullock and every bale of wool represented so much plant food taken from the soil, none of which went back again in any form. Johnson (*Agric. Chem.* p. 339) states that 1000 lbs. of raw merino wool yields 70-90 lbs. of potassium carbonate and 5-6 lbs. potassium chloride and sulphate. On this basis we may safely estimate that 1000 lbs. of Australian wool contains half a cwt. of potash. As Australia sends away over 500,000,000 lbs. of wool annually, this represents some 28,000,000 lbs. of potash, or an equivalent of, say, 25,000 tons of commercial sulphate of potash, worth, say, £300,000, taken from the soil each year. The difference between a crop of bullocks, wool or butter, and a crop of wheat or potatoes, is only one of degree.

The effect of stock on vegetation. Heavy stocking without tillage and fertilisation, however, does more than merely withdraw the plant food represented by the meat, wool, etc., sold. First, the stock eat out the most attractive and nutritious plants, so that the value of the pasture quickly deteriorates. From the point of view of soil fertility, this is one of nature's ways of guarding against depletion of the soil, because nature takes no account of whether her crops are, from man's point of view, weeds or not. Her law is, that when excess of animal life eats out the fodder plants or when the soil becomes too impoverished to support short-lived, quick growing, nutritious vegetation, she in due course, grows others which animals will not eat or which by their slow growth absorb plant food at a slower rate. These often open up the subsoil slowly, carry on the work of soil building, and in due time plant life gains the ascendency over animal. The rapidity with which she works depends on climatic conditions; for nature is in no hurry. Sheep and rabbits, in eating out the salt-bush and other drought-resisting herbage, have changed large areas of good sheep pasture into howling wildernesses. The lack of an



FILLING A TUB-SILO.

abundant supply of moisture has to be considered in this connection and is the governing factor in many cases where soil is still marvellously rich in plant food. Left alone, nature would in due course grow another crop of vegetation of some sort, possibly the same, although frequently she practises a rotation in such cases. In America, for example, it is found that if a forest of one kind of timber be destroyed its place is in time taken by another kind of tree. The rapid spread of introduced weeds in Australia appears to be an exemplification of this love of nature for rotation. We must not follow this subject now, but it may be well to give a definite illustration of the statement, that the heavy stocking of the land in the best humid districts of Australia has led to a very complete change in the character of the vegetation. Of his own knowledge. the writer could give many such examples in each of five States, but one will serve, and the reader will have no difficulty in finding local confirmation.

How a pasture deteriorates. A few years ago the writer and another bought a property in the south-west of Western Australia. The title deeds showed that the best blocks commanding the natural water supplies had been held in fee simple for over fifty years. At the time of purchase the rich alluvial flats and the almost equally rich adjacent slopes were in many cases covered with dense growths of young eucalyptus, acacias, bracken and scrubby herbage. The nutritious grasses and fodder plants were largely exotics. An examination showed that apart from the undergrowth of scrub and saplings under a foot or fifteen inches in diameter, the timber consisted of huge gum trees up to six and even eight feet in diameter, but of these there was not an average of more than two or three to the acre. Men who knew the place half a century ago, soon after it was first stocked, state that then the valleys were open park like country with rich natural grasses "as high as a horse," in the early summer, on which the cattle throve and fattened amazingly, and in the season seldom or never left the gullies and flats. When it is cleared once more, broken up and brought under rational cultivation with fertilisers, it proves to be as marvellously productive as it was in the early days.

The process of deterioration explained. The writer has investigated scores of similar examples in Western Australia, South Australia, Victoria, N.S. Wales and Tasmania, some extending over large areas, and, summarised, the explanation may be thus stated :—Before the advent of the settlers the ground was occupied with the few big trees and the dense growth of herbage against which tiny seedling trees had small chance of obtaining root room, or if they did get a start they would be completely destroyed by the tremendous heat of the fires used by the black fellow in his periodical battues on the rich lands which were the haunts of the kangaroo and other game.

The native animals kept in check by the black fellow could make no headway against the luxuriant feed, but the settlers crowded on their cattle, and they not only kept the grass down but trod in the seeds of the forest trees, thus at once planting the seeds and giving them room to grow. The settler as much as possible guarded against fire, but when fires did occur, or were purposely started late in the season to "sweeten the grass," there was not the former volume of flame to entirely kill the young trees, and thus the forests of young saplings and the undergrowth of wattles and scrub gained the mastery.

Nature rebels against overstocking and takes means to counteract it. The spread of sweetbriar, furze, African box thorn, blackberry, etc., in Victoria, Tasmania, and other States may be considered partly in the same complicated argument.

Effect of stock on the texture of clayey soils. In addition to eating out the more valuable herbage, stock often exercises a prejudicial and sometimes a remarkably destructive effect on the texture of the soil. Thus, constant treading in wet weather consolidates clayey soils, and this, with the great decrease in the supply of humus, soon leads to a condition unsuitable for the growth of the more tender and more nutritious fodder plants. This same consolidation also very materially decreases the absorbing powers of the soil and causes the rain water to run off the surface instead of sinking into it; and, with the water, the ashes produced by burning off the paddocks are also largely carried away to the sea. Burning off pastures is in a general way a penny wise and pound foolish custom. Every burn leaves the pasture in a permanently worse condition, for it not only deteriorates the physical condition of the soil but it acts as a handicap to the more hardy less valuable plants against the better but less robust fodders.

The trampling of stock on light sandy soils destroys vegetation and cuts up the surface, rendering it liable to be blown away by the hot dry winds of summer or washed away by heavy rains. There are large areas of what was in the early days of settlement splendid sheep country which are now moving wastes of sand. There are in every State large

PROLIFIC GROWTH OF "SPEAR" OR "CORKSCREW" GRASS.
The result of ring barking forest land in wheat belt of Western Australia.

extents of country on which pounds per acre must be spent to clear the forests of saplings and thick growths of scrub, and to break up the trampled soil, to destroy the harsh and useless herbage prior to seeding with useful fodder plants, before the land can be brought back to the stock carrying value it possessed when first settled. There are notable exceptions, but as a general statement it may be said that the pasture lands of Australia are very much poorer to-day than they were when the first settlers landed in each State. We are discussing soil fertility, not economics, and need not do more than refer to the lessened value of the pastures being represented by the homes of the people and much of the wealth of the cities. Neither need we do more than mention the fact that some pastoral properties carry more sheep now than they did in the pioneer days although the soil has lost much of its virgin richness. The reason is to be found in the destruction of the timber to make room for pasture plants, the conservation of water, the fencing of the land and division into paddocks, and the spread of exotic vegetation. That it is less rich than when first settled is known to everyone who compares the crops which may be now obtained without fertilisers from land which has never been cropped with those the pioneer farmers obtained from similar land in the early days of settlement.

THE PLANT AND HOW IT GROWS.

What plants consist of. Before we can understand the treatment of the soil it is necessary to study the plant which grows in the soil, because the nutrition of the plant is the object of cultivation and manuring. We all know that thousands of substances come from different plants, but these are all compounds which are manufactured by the plant out of a very few simple substances or elements. Plants have been analysed ; that is, split up into their most elementary substances, by many chemists very many times, and it has been found that all are practically composed of a very few of the elementary substances. This is not surprising when we remember that chemical research has demonstrated that everything on the surface of the earth is composed of a little over seventy substances called elements, simply because chemists have not yet been able to further divide them. Occasionally traces of most of these elements may be found in plants, but usually only thirteen occur in appreciable quantities, and of these thirteen only ten are absolutely essential for plant development.

The importance of water. On an average about 80 lbs. out of every 100 lbs. of green plants consist of water. The following may be taken as examples:

	Per cent.
Water plants and algae, from	95 to 98
Green cabbages, from	80 „ 94
Turnips, from	86 „ 93
Green maize, from	71 „ 93
Carrots, from	79 „ 90

Some woody plants may contain as low as 50 per cent. of water.

We know that water is composed of two elementary gases called oxygen and hydrogen, in the proportion of two parts of hydrogen to one of oxygen. We therefore have two elements in the water content of plants.

Dry or water-free matter. If we subject a green plant to a dry atmosphere under special conditions at a temperature something over the boiling point of water—that is, over 212° F.—all the water is driven off, and then we have what the chemist calls dry matter, or water-free material. The ordinary farmer speaks of wood, dry grass, straw, and even of hay as dry, but that only means that it is air dry; in other words, that all the water which can be taken out in a dry atmosphere under natural conditions has been removed; but the driest bit of wood or the driest bundle of straw on the driest day in the hottest summer will contain a considerable proportion of water. Usually hay and such-like material still contains about 15 per cent. of water, so that if we take 100 lbs. of air-dry hay and further carefully dry it by special means at a temperature of something over

212° Fah. we shall only have 85 lbs. of dry matter left.

FIELD PEAS—A MUCH NEGLECTED CROP.

Note the fine growth of haulms, but poor setting of pods. In a good crop each flower stalk should produce two pods and often three.

Carbon and carbohydrates. If we take this dry matter and analyse it we find that about half of it consists of an element called carbon, a substance with which all are familiar in the form of charcoal, coke and plumbago, which forms the ordinary black lead pencil. A diamond is carbon in a crystallised form, and, given sufficient heat, it will burn as does charcoal.

The remaining half of the dry matter is chiefly composed of oxygen and hydrogen, which are combined with the carbon to form the great variety of substances of very great importance, called carbohydrates, such as starch, sugar, cellulose, gum, etc. The carbon is associated with the oxygen and hydrogen combined in the same proportions as in water. We, therefore, see that this word carbohydrate, which puzzles many beginners in the study of plant substances, simply means a substance that is composed of carbon with the elements which constitute water. We must remember, however, that they are not in the form of water, but only in the same proportions. Fats and vegetable acids are also composed of the same three elements in different proportions. There are, in fact, hundreds of substances, composed entirely of these three elements, and the differences between such substances as starch, sugar, gum, and oil are due to the different proportions and conditions of the same three elements.

Proteins or albuminoids. We are all very familiar with the substances known as proteids or albuminoids, of which white of an egg is an example. There are very many of these, differing a great deal in their appearance and character, but they are all composed of carbon, oxygen, and hydrogen, with the addition of nitrogen, sulphur and sometimes phosphorus. These facts are stated in order to remind us of the vast importance of the four elements which have been named carbon, oxygen, hydrogen and nitrogen. The nitrogen, however, although of vital importance, only forms about two per cent. of the dry matter of plants. Another two per cent. consists of ash, the composition of which will be dealt with presently.

We, therefore, see that three elements—carbon, oxygen and hydrogen—constitute about 96 per cent. of the dry matter of plants, and the important element nitrogen, only forms two per cent.

Charcoal. It will perhaps help us to understand quite clearly the vast importance of carbon and the elements of water if we recall a few common and well-known facts. The farmer is perfectly familiar with the fact that when he cuts green wheat he only obtains, say, one ton of hay for four tons of his green crop. A fruit grower is also well aware of the fact that when he dries apples, grapes, or other fruit, he only obtains a small weight of dry fruit from a heavy weight of ripe fruit, the proportion varying with different fruit and its condition. We are all also familiar with the difference between the weight of a piece of green wood and a piece of dry wood. We also know that if we put a piece of any of these air-dry substances into a confined space, where it can be heated without being burned, a further greater reduction of weight takes place. The wood turns black, and we call it charcoal, and although it is of the same size as the original piece of wood it is very much lighter. In converting wood into charcoal we, in fact, drive off all constituents except the carbon and the ash. We are familiar with the same in regard to such substances as bread or potatoes, for we know that if the oven is too hot, instead of getting a loaf of bread or a roast potato, the result is a piece of charcoal. Put a lump of sugar in a very hot oven and precisely the same result follows, and instead of the sugar we have a lump of charcoal.

Charcoal bread at Pompeii. A very interesting illustration of the fact that by far the larger proportion of all dry vegetable substances is composed of charcoal or carbon may be seen in the museum of Pompeii. We remember that in the year 79 A.D., Vesuvius, which for centuries had been silent, suddenly became active, and in the eruption which followed buried the city of Pompeii many feet deep in hot cinder, ashes, and mud. Under the circumstances people left in a hurry. A baker had a batch of bread in his oven, but left without taking it out. A fruiterer had his figs and other fruits displayed in his shop window. He left them there in his hurry, and when nearly 1800 years afterwards the city was dug out, the remains of the fruit were found in their earthenware vessels, and the baker's batch of bread was found in his oven, though not just as he left it. The heat had simply driven off all the water, etc., and left the figs as lumps of charcoal in their natural shape, so that there is no difficulty whatever in identifying them after this long lapse of time. The loaves of bread, made in what is known as a cottage pattern, are very much the same as baker's make now, but they are simply lumps of charcoal, a substance which is almost indestructible when kept under such conditions.

Charcoal and ash. If we subject a lump of this charcoal, whether it be obtained from wood or from a loaf of bread or a fig, to sufficient heat it burns and gives out a great deal of heat in the operation. This burning is merely a recombination of the carbon of the charcoal with the oxygen of the air, the result being the formation of an invisible heavy suffocating gas, called carbonic acid gas, or carbon dioxide, in which one part of carbon is combined with two parts of oxygen. The nature and uses of this gas we will describe later. The heat produced during the combination of these two elements represents the energy or heat of the sun, which was used by the plant when growing, for ordinary plants can only form new material for growth by using sunlight and heat. When we burn coal the heat we obtain simply represents the energy of the sun stored up by the plants which lived perhaps a million years ago, when the vegetation which formed the coal beds were growing.

If charcoal is burnt we find, when all the carbon is completely consumed, that there is a small quantity of ash left, and the important point for us to remember is that this small quantity of ash represents the whole of the mineral matter which the plant obtained from the soil. We know how important it is to have rich soil for growing our potatoes, but when we burn a potato plant (top, roots, and tubers), we find we have left only a very small quantity indeed of ash, and that ash is all the potato plant obtained from the soil during its growth.

The ash of plants. The ash of plants varies in quantity and composition with different plants, but, as we have previously mentioned, it may be stated to represent on the average about two per cent. of the dry material. Let us just consider for a moment what this means. We have said that a cabbage may consist of 94 per cent. of water, leaving only 6 lbs. of dry matter out of 100 lbs. of cabbages. Of this less than one per cent. is ash, which was obtained from the soil. This is worth thinking over. Why should it be necessary for us to apply so much fertiliser to our garden land when 100 lbs. of cabbages can only take about one oz. of mineral plant food? We shall see later on that, in taking up this ounce of mineral matter from the soil, the cabbages drew out of the soil, through their roots, over one ton of water, most of which, of course, was evaporated into the air.

If the small quantity of ash obtained from burning the plants be analysed, it is found to practically always contain nine elementary substances, six only of which are absolutely essential for the development of the plant. These substances are:—(Essentials): potassium, phosphorus, calcium, sulphur, magnesium, and a little iron. (Non-essentials that are almost always present): silicon, sodium, and chlorine.

Water cultures. A very great number of experiments have been carried out by investigators to determine what substances are absolutely necessary for the growth of the plant. Two methods are adopted. One is known as water culture, and the other sand culture. The water culture is perhaps the most convincing and the least free from possible error. It may be described as follows: A number of glass jars are taken, each one fitted with a glass top through which a stem of a plant may pass, but fitting closely enough to prevent the contamination of the water. These jars are filled to a certain height with perfectly pure water, plus the substances to be experimented with. One jar will have pure water alone, another will have a complete plant food in solution, and each of the others all but one of the substances contained in the complete plant food. There will be one jar without combined nitrogen, one without phosphorus, another without potassium, another without calcium or lime, another without magnesium, another without iron, another without sodium, another without silica, another without chlorine. These will give a set of twelve jars. The nitrogen used in the solutions must be nitrogen in combination, and the other elements are also provided in soluble chemical compounds.

Necessary plant foods. Germinated seeds are then taken and carefully suspended in the jars over the water, so that the roots will hang into the water and the stems pass up through the glass top into the air. It is found that when the plant is provided with the following elements in solution, it will make a complete development. The necessary plant foods are: nitrogen in combination, potassium, phosphorus, lime, sulphur, magnesium, and a little iron. The plants growing in the jars from which any one of these substances is omitted will not fully develop. The one growing in the pure water dies as soon as the plant food contained in the seed is exhausted, others will live for varying lengths of time and make varying amounts of development, but in no case is development complete. Plants growing in the watery solution in which the above elements are complete will make a full growth and mature seeds. The experiments show that, although silicon, sodium and chlorine are practically always present in plants often, as in the case of silica in wheat, in considerable quantity, they are not essential for the development of seeds.

Sterile sand cultures. If, instead of growing the plants in water, we grow them in carefully prepared pots, filled with pure quartz sand and watered with the solutions, the same as contained in the jars above mentioned, similar results are obtained. These experiments demonstrate exactly what materials are obtained through the roots by means of water. The other essential element in the structure of a plant is carbon, which is obtained from the carbonic acid gas of the air through the leaves, and this can only take place in the presence of sunlight, which supplies the energy necessary for the process.

Carbonic acid gas, or carbon dioxide. Carbonic acid gas is a combination of carbon and oxygen, one portion of carbon being combined with two portions of oxygen. There is less than one per cent. of it usually in the atmosphere, but from this small quantity all the charcoal of the plants of the world is derived. All are familiar with carbonic acid gas, for it is the gas which produces effervescing in baking powder, lemon kali, lemonade, soda water and champagne. It is the gas which is produced in dough when yeast is working, and the small bubbles, by separating the particles of dough, make the bread light. If breathed by man or animals it is suffocating. When taken in moderate quantities into the stomach, it is wholesome and beneficial.

When charcoal burns, the carbon of the charcoal combines with the oxygen of the air and produces this carbonic acid gas, or carbon dioxide. It is well known that if a room which is not ventilated is heated with a vessel of burning charcoal, the result is the consumption of the whole of the oxygen, and the death of any persons who may be in the room. When the oxygen is consumed the charcoal will no longer burn.

Carbonic acid gas is heavier than air, and sometimes accumulates in the bottoms of wells, and in fermenting vats in breweries and wineries, and it is always a safe precaution before entering a well or a vat to lower a lighted candle. If there is an accumulation of carbonic acid gas the candle will go out, and where a candle will not burn man cannot live. The difference between the price of a glass of water and of soda water is entirely due to the carbonic acid gas the latter contains.

How the leaves obtain their carbon. By aid of their green colouring matter, which is called chlorophyll, the leaves have the power in the presence of sunlight of absorbing the carbon dioxide of the atmosphere and of splitting it up into carbon and oxygen. The oxygen they reject, and it passes back again into the air. The carbon is retained and is combined with water and the mineral substances held in solution by the water, and from these all the complicated substances found in plants are elaborated.

Essentials for plant growth. We therefore see that the absolute essentials for ordinary plant growth are water, with the seven soil plant foods previously mentioned dissolved in it; carbonic acid gas or carbon dioxide and sunlight. If a plant is placed in a vessel from which all the carbon dioxide has been taken from the air it can make no growth whatever. When carbon dioxide is introduced into the vessel, growth takes place, and if a little excess of this gas is added growth is more rapid than in the ordinary atmosphere.

One point may be mentioned here, although it is not necessary to dwell upon it. We have mentioned that the leaves take in the carbon dioxide from the atmosphere, and after making use of the carbon the free oxygen again passes out into the atmosphere. The action of plants, therefore, tends to keep up a supply of oxygen, which is so necessary for animal life, and also to reduce the proportion of carbon dioxide, which is injurious to animal life. It is often stated that plants take in carbonic acid gas and breathe out oxygen, whereas animals take in oxygen and breathe out carbonic acid gas. While this expresses a general fact, it should be remembered that to a certain extent plants also absorb oxygen and give out carbonic acid gas. This is an interesting fact in connection with the physiology of plants, but it is altogether overshadowed by the importance of the absorption of carbon.

Osmosis. Water with its dissolved plant foods is taken up by the roots of plants by the physical property called osmosis. By osmosis is meant the power which liquids of different density have of passing through a membrane or an intervening porous substance. An example may be obtained by filling a pickle bottle with a solution of sugar and water, and tying over the top a covering of bladder. Turn the bottle upside down, and it is found that the water will not run out; but immerse that bottle in another vessel containing pure water and water will pass into the bottle until the bladder has stretched to a very great extent, and if the sugar solution is fairly strong the bladder will burst, owing to the very great pressure from the inside. While the water is passing into the bottle the sugar is slowly passing out into the pure water outside.

This process, which is due to the fact that liquids of different densities have the property of passing through porous substances and mixing until they become equally dense throughout, is called osmosis. The water passes into the roots through the little root hairs which are found only on the younger portions of active or growing roots. When a plant is in active growth new roots are continually growing, and on these are the root hairs through which the water enters. The water with the plant food dissolved in it passes up the stem, but not through tubes or pipes, as many suppose, because the current, if it may be so called, is really from one cell to another by this process of osmosis.

The importance of water to plants. Without water there can be no life. We have seen that water itself may constitute up to 98 per cent. of the total weight; and that of the water-free or dry substance, the elements of water make up about half. It is only when the living portions of any organism are permeated with water that their vital processes can be carried on.

An Irrigation Channel and Lucerne Plot being Flooded.
Brunswick State Farm, Western Australia.

Protoplasm is the vehicle of life. Many of the secrets of the nature of protoplasm are not known. When living, it is normally of a viscous thin fluid consistency, and when freed from its water it either dies or becomes perfectly inactive. In many cases, as in spores and seeds, and in some drought-resisting plants, it may endure a considerable amount of drying for a longer or shorter time. Under such conditions its functions entirely cease, but in spite of the drying some water is still retained.

Sprinkler Irrigation and Vegetable Growing, Mount Lofty, South Australia.

Within a radius of two miles of the spot shown there are hundreds ot acres of vegetables and over forty sprinkler irrigation plants worked direct from force pumps driven by oil engines.

The use of water to the plant may be thus summarised :

1. It is the agent which permeates and energises the plant cells.

2. It is the medium by which nutrition is carried on.

3. It dissolves and is the medium through which the plant absorbs the soil constituents.

4. It conveys soil plant food to the leaves where assimilation takes place.

5. By its transpiration or evaporation from the leaves, etc., it keeps the plant cool in hot weather. This evaporation leaves the mineral substances behind, and the plant is thus able to accumulate sufficient for its needs. Soil water is never pure, but the solutions are normally very weak. When the functions of a plant are active there is a constant current through it. As far as is at present known, the forces which produce this current are osomotic pressure and capillarity.

Quantity of water required by plants. The quantity of water transpired by plants has been frequently investigated. It varies with different plants, and the conditions under which they are growing, but may be said to be from 200 to 500 lbs. for each pound of dry matter produced.

In South Australia and Western Australia the writer has investigated authentic instances of over one ton of wheaten hay having been grown with from 6 to 7½ inches of rain, generally on fallow, but also on stubble land.

In 1908, the rainfall from January 1 up to the end of September, at Nangeenan, Western Australia, was 875 points, of which about an inch fell in a thunderstorm at the beginning of the year, leaving about 7½ in. for the growing period, and this was badly distributed. There was an excess in May and a shortage in August and September, this shortage being accompanied by most unusual frosts. Under these conditions, crops which were sown early on fallow land, so as to secure the whole of the $7\frac{1}{2}$ ins. of rains, yielded from one to two tons of hay to the acre. The rainfall at Kellerberrin was slightly higher than at Nangeenan, but the crops were about the same.

On Mr. W. Ripper's farm at Wollandra was a field of Whitelock wheat, estimated to yield 25 to 30 cwt. of high quality hay. The crop stood from 30 ins. to 4 ft. high, with clean strong growth and a lovely colour. The crop was sown on March 25 on land which carried a crop the previous year. Just before seeding it was worked while dry with a disc cultivator, then drilled with a bushel of seed and 56 lbs. of superphosphate. On the same farm, crops sown about the same time on fallow land were considerably better

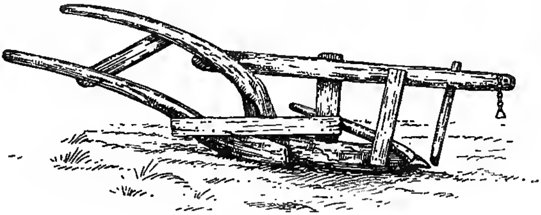
A Wheat Farmer's Pioneer Home, Western Australia.

than the above. They were being cut for hay, and in places were yielding two tons of hay to the acre.

It will be interesting to see how the theoretical requirements were met by the conditions stated. On account of the dry atmospheric conditions of the district it will be well to allow for the maximum of 500 lbs. of water for 1 lb. of dry matter. If the air-dry hay contains 15 per cent. of water, a ton of hay will contain 1904 lbs. of dry matter. An inch of rain over an acre of land (an acre inch) is 22,640 gallons and weighs 110.7 tons. Calculation shows that a ton of hay does not require to use more than about 3.8 ins. of rain. Of course, a crop can only use part of the rain that falls, even if it all enters the soil, but this shows that a ton crop of hay only uses about half of a 7½ in. fall, leaving the other half for soil evaporation and other waste. The two-ton crops referred to were growing where there was probably some accumulation from higher land.

TILLAGE OF THE SOIL.

TILLAGE embraces all the operations undertaken by the farmer, fruit grower or gardener, in order to improve the physical condition of his soil and render it better fitted for the growth of crops. The lady with her garden gloves and sun-hat, pottering round her plants with a trowel or toy hoe, is tilling the soil, and the engineer, with a big traction engine drawing several gangs of heavy ploughs, is doing likewise. The first tillage implement of primitive man was a pointed stick, and the latest is—well, if we try to name it, the statement will probably be wrong by the time this is in print. From the pointed stick to the Australian stump-jump or the American Oliver plough is a long, interesting story of irregular but



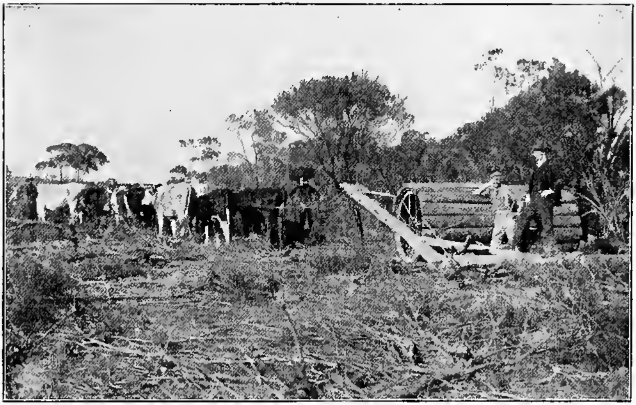
HENTY'S FIRST PLOUGH.

gradual progress, for the Egyptian fellah, the primitive Turk, and the Indian native of to-day, use much the same type of wooden plough as the ancient Roman or Greek husbandman did.

The difference in methods of tillage of to-day, as compared with ancient times, is almost entirely a matter of implements. An Australian farmer, with his strong team and modern plough, not only does as much work in a day as would have taken many men to perform in the olden time, but he does it better. In spite of high wages, the Australian ploughman does better work at less cost per acre than the Turk who receives 1s. 6d. a day as wages. In the writer's boyhood days, an acre was a good day's work with the old narrow mould board plough and two horses. To-day, the modern Oliver plough will do two acres and do it better, while one man with six horses and a four or five furrow plough will turn over from four to seven acres, according to soil and depth. Similar comparisons might be made in respect to all tillage operations.

There are many tillage implements, suited for every class of work under all conceivable conditions. Some work the ground deeply, some turn it over, while others stir the surface only; some are specially designed to cut and destroy weeds, the special purpose of others is to create a soil mulch; one loosens the soil, another consolidates it. Whatever the name and whatever the special design, all have for their object the bringing of the soil to a more perfect condition as a home for the various crops of the farmer.

What tillage does. Tillage is the oldest, commonest, simplest and most varied of all the operations of the agriculturist; but few of those who thus industriously plough, scarify, harrow, roll, dig, rake, hoe, and so forth, ever attempt to put into words the reasons for their diligence. They know from experience that, other things being favourable, the crop will be in proportion to the wisely directed tillage the land receives. We must not forget the qualification "wisely directed," for badly directed work may do harm. No one can learn to till the soil from a book, but the reason why tillage is good may be set forth, and knowing why enables the thoughtful man to decide how.



A Home-made Scrub or Mallu Roller, for Crushing Scrub prior to Burning.

Two points are obvious to all:

1. It is necessary to stir the soil in some way to make a mellow seed bed, and all know how important this is in giving the plant a good start.

2. The soil must be kept free from weeds if crops are to thrive. Tillage is the readiest means of accomplishing this purpose. Many people, even to-day, think of no other reason for stirring the soil, apart from preparing the seed bed, except to keep down the weeds; but, in so doing, they do much more. To such people weeds are sometimes a blessing.

Tillage to conserve moisture. The orchardist usually adds another reason, and so does the farmer who judiciously works his fallow after rain. Cultivation provides a soil mulch to retain the moisture in the soil. The fruit grower has now learned this lesson fairly well, and there are no better cultivated orchards in any part of the world than in Australasia. For all summer crops tillage for this reason is necessary. W. P. Snyder, Superintendent of the Nebraska Agricultural Experiment Station, found that the soil of a maize field, which had been cultivated frequently, contained 17 per cent. of moisture in the soil from 9 to 17 inches deep, while a part of the same field, which had not been tilled, contained only 12 per cent.

The writer does not know of exact moisture determinations having been made in Australia on fallow and unfallowed land in summer; but an example of a farmer's experience is, perhaps, equally striking. In Western Victoria a farmer decided to put down a tank or "dam" to serve two paddocks, one of which was under well-worked fallow, and the other was having its year of rest. Part of the division fence was removed, and the tank was excavated half in one paddock and half in the other. The work was done at the end of summer, and after the first few inches of surface soil the earth under the fallow field was moist right down to the full depth of the dam, while that under the uncultivated land was dry all the way. One of the men who operated the plough and scoop said they could see the difference almost to a foot all the way down. What struck him was the clear line of division down to six or eight feet.

Deep tillage enables a stiff soil to absorb water more freely and fully, and shallow surface tillage prevents the loss of the water by evaporation. The means by which this end is attained constitute what is known as "dry farming," a much misunderstood term which originated in parts of America where the climatic conditions are very different from most of the wheat areas of Australia. Reliable American advice on dry farming largely applies to country which is frozen in winter, and has a spring and summer rainfall of from fourteen to eighteen inches. What is good in it is not new; and what is new seldom applies to Australian conditions, where most of the rain falls in the cool growing season.

Tillage is also necessary for its beneficial influence on the useful bacteria in the soil. Modern science has provided explanation for many proved agricultural operations, but none is more interesting than this. The important work performed by the micro-organic life of the soil is referred to elsewhere; but in order that the beneficial bacteria may thrive, the soil must be warm, moist and well supplied with air. If too wet, too dry, too cold or too hot, beneficial bacterial action is retarded. Tillage provides the favourable conditions. While the gardener is hoeing potatoes to kill the weeds he is helping his myriads of unseen friends to provide available plant food for the plants. The original use of the word manure meant to till the land, or to work it by hand, and modern science shows that the operation has a significance the old users never dreamed of.

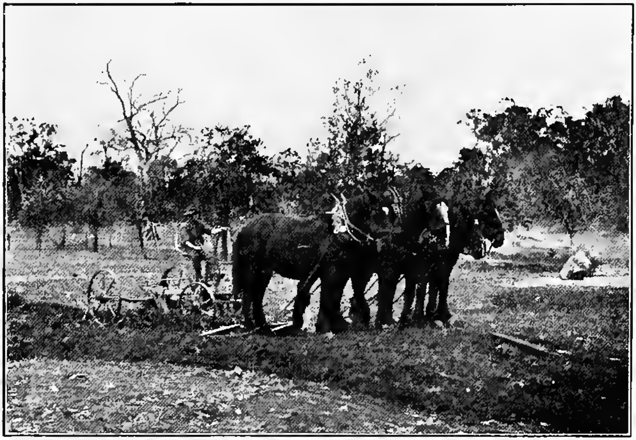
The only way to learn the practical operations, which may be grouped under the word tillage, is by working the various implements on farm, orchard or garden. All that we can do is to classify the chief tillage operations and outline the general purpose of each.

Ploughs: their history and use. The plough is a very ancient type of tillage implement, and its use dates back beyond the dawn of history. The first plough was a forked sapling, or tree branch. One fork was cut short and sharpened; and the other, left long, formed the beam. A third formed a handle, or one was lashed to the beam with thongs or fibre. This crude implement, operating on virgin soil, naturally friable, stirred it to a depth of a few inches without inverting it, and was all that was at first necessary. The tillage operations on virgin soil in many parts of Australia in the early days were no more thorough; and to-day, better results are often obtained from newly cleared forest land in the wheat areas of Western Australia from merely scratching the surface with cultivators to a depth of from two to four inches, than from turning the land over with a plough. Looking merely at the results, without considering the reason, a visitor to one of the pioneer districts recently expressed the opinion that his inspection led to the conclusion that "the worse the farming the better the crops." That is the danger before the settler. It is quite in accord with the principles of modern agriculture that such land should give better results from mere surface stirring of the soil than from being well ploughed. The surface is sweet, rich and friable, the lower soil is not so. To turn up the under soil with a plough may be compared to turning up the subsoil of a fertile field. The mistake so many made in the past, and others are making to-day, is to think that such pioneer methods are applicable to all soils, and that they can be continued. They cannot, but it is interesting to carry the imagination back perhaps four or five thousand years and see primitive men laboriously rooting up the soil with a pointed stick, and then watch the pioneer settler in Australia riding behind a good team and doing similar work with a modern disc or spring-tooth cultivator, scratching ten to fourteen acres a day, and a few months later harvesting a twenty-bushel crop. It is not always wise to cast reflections on the methods of primitive man, any more than it is to criticise pioneer work too closely.

It is stated that ploughs with iron points were first used in the eleventh century. Cast iron shares were made in 1785 and chilled shares in 1805. These dates are mentioned to show how recent is the great development in tillage implements. Fletcher states that an American farmer patented a cast iron plough in 1797, but it did not become popular because farmers believed that iron ploughs "poisoned the land" and "caused weeds to grow." It was not until the latter half of the nineteenth century that plough makers began to realise that the proper function of a plough was to pulverise the soil. Even in the writer's memory ploughing matches were popular in South Australia, and the prize ploughing was partly judged by the perfect inversion and unbroken continuity of the furrow slice. It was pretty ploughing, but poor tillage. The great difference between the plough to-day and that of a generation ago is that the modern plough, of which the Oliver may be taken as a type, has a broad flat share with short overhanging mould-board, which so twists the furrow slice that it pulverises it rather than inverts it.

Australian conditions have led to the development of several special types of ploughs, the most noteworthy feature of which is the stump-jump invention of Mr. R. B. Smith of South Australia, in 1876, combined with the American short pulverising mouldboard, broad share and multifurrow or gang principle. The American disc plough, with its Australian adaptations, including the stump-jump principle, has also secured a place in the favour of the Australian farmer for some classes of land and for summer ploughing.

The labour question is one of such vital importance that practically all Australian ploughs, as well as other agricultural implement inventions, are the outcome of a desire to lessen the number of farm hands required for seeding and harvesting the large areas of crop necessary for success under present methods of wheat growing. By these inventions thoroughness is sacrificed to area. Where this is due to the uncertainty of the climate, nothing need be said; but it is not too much to say that reform is in many cases urgently necessary in favour of intensive rather than extensive farming. Speaking generally, but emphatically, with regard to districts with regular rainfall, many farmers might well learn to plough fewer acres but plough better. This statement is made while fully recognising the fact that profit on the year's operations, not the biggest yield per acre, is the business aim of the



A STUMP-JUMP PLOUGH AND TEAM PLOUGHING MAIZE STUBBLE DRY.

farmer; and that the bank balance is the popular measure of a farmer's success.

The objects of ploughing. The objects of ploughing the land are:

1. Pulverising or crumbling the soil, to prepare a good seed bed. This work is continued with the cultivator and harrow.
2. To destroy wild plants and weeds so that the more delicate cultivated plants may be more readily grown in their place. The plants grown by farmers owe their present value largely to the improvement of man during many centuries. They are vigorous when grown under suitable artificial conditions, but from nature's point of view lack constitution. They are not capable of withstanding the competition of indigenous vegetation or vigorous introduced weeds. Highly developed fodder plants and old world grasses as a rule will not establish themselves amid the competition of natural vegetation which has secured possession of the land for thousands of years. Still more does this apply to field and garden crops.
3. Ploughing turns in the growing and dead vegetation, stubbles and so forth, and places it where it will decay and add to the organic matter or humus of the soil.

A plough is good in proportion as it accomplishes these three objects. The old style prize flat ploughing looks pretty, but the modern rougher crumbling surface is better. No one plough will do equally satisfactory work under all conditions, and therefore the farmer often finds it necessary to have several. The kind of plough to use depends on: (1) the nature of the land; (2) the time of ploughing; (3) the object of ploughing, *i.e.* whether to prepare a seed bed or leave the ground rough and open to the influence of the weather; (4) the kind of crop to be grown.

The depth to plough. If it be desired to secure a vigorous debate in any conference of farmers, no better subject can be introduced than the merits of deep and shallow ploughing. It is quite certain that in an hour the uninitiated will become absolutely confused with the contradictory evidence given and the opposite opinions held by experienced and reliable farmers. If the confused listener takes the trouble to visit the farms of the debaters, he will find that the supposed opposition does not really exist. Each farmer speaks of his own experience under some special conditions. The fact is no general statement can be made. The old saying ran:

> "Plough deep while sluggards sleep,
> And you will have corn to sell and keep."

It is true enough under some conditions, but means ruin under others. The depth to plough depends chiefly on the nature of the soil. The nature of the crop has also to be considered. Some crops feed deeper than others. Ploughing, or at least stirring the soil deeply for orchards and vineyards is almost always advisable. The so-called heavy, *i.e.* clayey soils, usually require deep ploughing. It may not be, indeed often is not, wise to turn over even such soils deeply when first bringing them under cultivation; but sooner or later deep cultivation becomes necessary. Experience and judgment alone can decide, and this cannot be learned by reading. It is usually a wise thing to at first plough new land shallow, and go a little deeper every year. The subsoil sets a limit to the desirable depth to plough. It may be given as a sound maxim that the subsoil should be stirred, but not brought to the surface. Shallow soils may, however, be very gradually deepened by going a little deeper now and then. Light soils do not as a rule require deep ploughing, and are often injured by it. It is wise to keep on the shallow side and experiment with strips ploughed deeper. Perhaps the whole matter may be summed up in the advice to work the soil as deeply as its nature will permit and, if it be shallow, persistently endeavour to deepen it in order to increase the feeding area for the roots of the crops to be grown. Roots of ordinary plants penetrate to a depth of several feet at least, but they feed mostly in the tilled soil, therefore let this be as deep as circumstances will permit.

Subsoiling. Subsoiling means loosening the subsoil for some inches, say, down to a foot below the ordinary ploughing. Enthusiastic advocacy of subsoiling, like measles, becomes epidemic at times. Much that has been said of the depth to plough applies to subsoiling. In some cases it cannot be advised too strongly; in others it may do more harm than good. Wherever the subsoil has a tendency to be close, so that it does not permit of the access of air and allow the free movement of water, subsoiling is, as a rule, desirable.

The benefits in some cases are enormous. Especially is it desirable to subsoil a field with a clay subsoil which has been underdrained, but it is unwise to subsoil clayey soil when wet, for the result is to puddle the clay and further injure its physical condition.

Draft in ploughing. The ploughman must learn by ploughing. He must learn how to set his plough by actual demonstration and practice. All that can be done here is to show how important it is to study the plough, experiment in its use, and, above all, get hints from experienced, thoughtful men. Fletcher states that it takes 55 per cent. of the total draft in ploughing to cut the furrow slice, and 12 per cent. to turn it. This leaves 33 per cent., or one-third of the power used, as being absorbed in friction of the plough sole and land slide. An old blunt share makes ploughing as hard for three horses as a new point does for two. Referring to single furrow ploughs, it is stated that a plough not adjusted properly may require 50 per cent. more energy to move it. The use of a knife colter increases the draft, while a beam wheel lessens it. The deeper a plough works the less draft it requires in proportion to the size of the furrow slice, *i.e.* it does not take twice as much power to turn an eight-inch furrow as one four inches deep. The wider the furrow the less the power required in proportion to the soil turned. With a bold mould-board a furrow may be turned two or three times as wide as it is deep. There should be plenty of power in front of a plough if the most economical and effective work is to be done. Quick horses not only do more, but do better work than a slow team. The ploughman should remember that a plough, fitted for its work and properly adjusted, should run in the soil as though it liked being there. It should not require to be held there. If it does, he should not rest satisfied until he has adjusted it properly.

Cultivating and harrowing. What the hoe and the rake are to the gardener, the cultivator and harrows are to the farmer and orchardist. The work of pulverising the soil, begun by the plough, is continued by the cultivator, and finished by the harrows. Sometimes these operations are reversed. Under special circumstances the work of these implements is supplemented by the roller. As soils and conditions vary, and farmers have to prepare uncongenial soils, it becomes necessary to have as great a variety of cultivators and harrows as of ploughs. Apart from the work of preparing the seed bed, the cultivator and harrow are necessary in the work of destroying weeds, and preparing and preserving the soil mulch so important for conserving moisture and promoting bacterial action. It seems strange, but it is true, that while good tillage, under some conditions, is proportional to the amount of cultivation, under others, working the soil is positively harmful, and, in a general way, the farmer must be guided by his special conditions.

Cultivation may be desirable, but not sufficiently so to be profitable. Cultivation and harrowing should not be done when the soil is too wet, or when it is too dry. There is an exception to this statement. When soil is very light, sandy and open, the wetter it can be worked the better in order to consolidate it. To work heavy land under such conditions destroys the mechanical condition by puddling it, and working it when too dry reduces the soil to dry dust, so that it will not absorb water freely. In such a case, unless the rain comes very gently, it will run off, perhaps washing away the soil. When it does become wet, it runs together, is very sticky and bakes hard when drying.

It is, as a rule, wise to cultivate summer crops and orchards while there is yet plenty of moisture in the soil, and provide a good soil mulch. It is also wise to cultivate after a summer rain, but it is, as a rule, waste of energy, or positively harmful, to work dry soil. It is necessary to make all these qualifications, because conditions vary much in different parts of Australia. Where there are summer rains, the rule is to cultivate the fallow and orchards after every shower; where there are no summer rains, it may be either useless or harmful to work the dry soil.

Kinds of cultivators and harrows. There are many makes of cultivators and harrows, each having its own special use. A cultivator may be taken as a magnified harrow, and what applies to one applies to the other. The various makes may be reduced to four types:

1. The spike tooth harrow, which pulverises the soil and at the same time compresses it. The effect is different according to the set of the spikes, *i.e.* whether they are vertical, slope forward or backward.

2. The spring tooth harrow, which lifts the soil while pulverising it.

3. The acme harrow, which slices the soil and also turns it or stirs it.

4. The cut away or disc rolls over and cuts the soil. In addition, there is the chain harrow, which is really a smoothing implement.

Implement Shed in course of Erection, ready for Thatching.

There is no best harrow, just as there is no best plough. Each type is best when used under the conditions for which it is most suitable. It is, therefore, necessary for the buyer to know his conditions, and buy the implements which will suit them best. Each type has many modifications, and, unfortunately, salesmen think only of selling, and not of the use which the farmer has for the tool. An implement which will do excellent work on a field one week may be unsuitable the next, because in the interval the soil may have become too wet or too dry for its effective use. In cultivation to kill weeds, the essential point is to attack them when they are young and easily destroyed.

Rolling. Few tillage operations are harder to explain than the use of the roller, because some of its effects are contradictory. Everyone knows that the grain sprouts quickest where the horses have trodden when harrowing, or where the driver of the drill happens to have pressed the soil over the drill line. Gardeners have a practice of treading along the line of newly sown seed. Every observant person has also noticed that the soil looks moist in a footprint of man or horse or in a wheel track. Farmers also know that the surface of a rolled field looks moist when a harrowed one is dry. Consolidating the soil, either by trampling it or rolling it, brings the moisture to the surface, where it readily evaporates and is lost in the air.

Rolling cannot increase the amount of moisture in the soil; but it may hasten the germination of seeds by bringing it to them. On the other hand, it causes a loss of moisture by bringing it to the surface, when it is readily lost by evaporation. It often pays to cause this loss in order to secure the benefits of quick and regular germination. Rolling also increases the evaporation by producing a smooth surface, over which the drying wind passes more rapidly than over a rough one. Rolling light soils, by compacting them, really increases their capacity to hold water; but to secure this benefit, the surface must be harrowed after rolling to produce a soil mulch. This is often a desirable practice.

Rolling is often desirable to crush clods and give a smooth surface to permit the hay crop being cut close to the ground. An additional two to four inches of hay may often be saved in this way, and on a crop this may mean a saving of from seven to ten per cent. In rolling when too dry the lumps are often merely pressed into the soil.

FALLOWING.

FALLOW is a period of rest. As used in Australian agriculture, it means what in English farming is called bare fallow. The land is ploughed in winter, cultivated in spring, before the moisture dries out of the ground, and is allowed to lie, with or without further cultivation, until seeding time the following autumn. The amount of cultivation given to fallow by good farmers, depends on various conditions of soil and rainfall; as well as the necessity for destroying weeds. No positive rule can be laid down. In Western Australia especially, and in the other wheat growing States, when summer thunderstorms are very rare, the working of the fallow in the summer is generally to be condemned. To cultivate light sandy land dry is seldom wise; and to work clayey land into a fine powder when dry is at all times to be avoided. A fine dry powdery soil absorbs rain very slowly, and, when the immediate surface is wet, it swells, forming a layer of soft clay, through which water will not percolate freely. The finer and dryer the surface soil, the more slowly does the rain penetrate, and, if the surface is undulating and the rain heavy, the water quickly runs off to the lower ground, forming tiny streams of mud-charged water, which join and gather force and wash first little gutters, then greater channels, and, if the fall be heavy enough and the area large enough, finally, great washaways or gulches.

Working fallows. Judgment is necessary in working fallows, and contradictory results are not infrequent; but the following principles appear to be in accord with general experience:

1. Very sandy soil is best ploughed and worked wet to keep it as solid as possible. The surface may be broken for an inch or two in spring, but it should not, as a rule, be worked in summer, especially where it is liable to be blown away.

2. Heavy clay land should not be ploughed dry, because it breaks into great clods which are very difficult to deal with. It should not be ploughed when too wet, for the action of the plough sole puddles the bottom of the furrow and also the furrow slice with which it comes in contact. The soil does not crumble but sets in long, hard clod-like masses, which resist all efforts to bring them into good tilth. The farmer cannot make the weather to suit him, and cannot always choose the right time for ploughing his heavy land, but he should do so as much as possible. The right time is when the furrow slice crumbles as it turns, and the earlier the fallowing is done the better. What he should try to do with such land is to improve its mechanical condition by the use of lime and the addition of humus.

In spring, before the soil bakes, it should be worked deeply with a suitable type of cultivator, to thoroughly break up the furrow slices and fill up the hollow spaces which are always formed in ploughing such land. The surface should be left loose and crumbly so that it will act as a soil mulch, and yet be open enough to readily take in water and not run together. The surface for two or three inches should be stirred after rain, before it bakes, in order to maintain the soil mulch and to provide the open condition for the next rain. We may repeat the advice, never work such soils down to dust, for that is the very best way to injure the physical conditions.

3. The various types of loamy soils fill up the wide range between those mentioned under 1 and 2. Midway is the mellow loam, which gives the greatest latitude in working and is the ideal soil. Writers, however, do not appear to see the humour of their very general recommendation to select good loamy soil for nearly every crop, regardless of the fact that the farmer does not make the soil, but works what nature has provided, and he can only modify it within certain limits.

The accepted general rule is to fallow as early in the season as circumstance will permit. Before the rainy season closes, work the fallow with the best type of cultivator adapted for the particular class of soil. In this working the object is to break up the furrow slices, fill all open spaces, and so pack the soil stirred by the plough, that it will be in close contact with the unmoved subsoil, and will form a continuous firm but sufficiently open mass through which film water may move readily by what is popularly called capillarity, the meaning of which has been explained elsewhere.

Before the moisture dries out of the soil, the surface should be stirred with suitable light cultivators, or, in light soil, with harrows, in order to provide a soil mulch, so important in preventing evaporation, and at the same time providing the best possible conditions for the active work of the micro-organic life of the soil, which produce the all-important bio-chemical changes which render plant food available.

Beyond this we do not know of any benefit to be derived from further working of the soil. If rain falls and cakes the surface, it should, if circumstances will permit, be again broken to re-establish the soil mulch as quickly as possible; but we may again repeat that the evidence seems strongly against working the soil in a dry condition. The teams are better resting and the men are better employed at other work.

In the above notes, the soil only has been considered. The presence of weeds introduces another self-evident factor. If weeds threaten to foul the fallows and they cannot be dealt with by sheep, cultivation is necessary to destroy them. Some old sayings will not bear investigation in the light of modern knowledge; but the Australian farmer is well able to bear witness to the truth of the old saw:

> "One year's seeding is seven years' weeding."

Seeding fallows. According to accepted theory seeding should not be commenced until the first good rains of the season have started the weeds. The fallow should then be cultivated to destroy them, the drill following as quickly as possible. Unfortunately, to attempt to carry out such a routine is practically impossible over wide areas of the wheat-growing country. In ordinary years, to get the seed in the ground at all, it is necessary to put it in before the rains. Fallow prepared as previously described is ready for dry seeding, and this is another strong reason for preparing the land in spring, while the ground is in the proper condition for cultivation. It not only conserves moisture in the ground, a matter of vital importance, but prepares the seed bed. Early seeding is absolutely necessary in the drier wheat areas, and in districts with greater rainfall and longer seasons it is also in many cases to be recommended, later or longer season varieties of wheat being sown. There is no practice more clearly demonstrated by experience than this. Early seeding can only be done well on fallow worked, as has been indicated, in spring.

Seeding dry ground has been and is often condemned as wrong in principle, and few, if any, would adopt it from choice ; but right or wrong, it is a general practice and must continue to be, simply because it is the only way by which the wheat farmer can be sure to get a large area under crop. He must seed early, and, if the rains do not come in time, he must sow dry. While it leads to disaster at times, experience has proved that the results justify the general practice, and it is worth considering very briefly the principles involved.

Nature's plan. Nature sows her seed on the dry ground and they fall into cracks, are buried by insects, trodden in by animals or covered by dust. Sometimes they are adapted by nature for covering themselves, and such provisions form interesting subjects for nature study. One of the most striking examples is the seed of the wild geranium, widely distributed over Australia. When dry, it has a long tightly-coiled awn, which when moistened slowly uncurls itself. The point of the seed is sharp and this twisting works the seed into the ground. When the awn dries it curls up again, thus twisting the seed in the opposite direction and further forces it into the ground. This process goes on often, as there is dew enough to provide the moisture, and by the time the rain comes the seed is planted. The seeds of some of the corkscrew and spear grasses also afford good examples of nature's planting methods.

The important fact is that the wild seeds are sown early, are subjected to the intense dryness and heat of the summer and spring up with marvellous vigour when the rains come. The seeds of cultivated crops are not as hardy as those of wild plants, but self-sown wheat, oats and barley, behave in the same way. Then why is it wrong to follow nature and seed our fallows dry? The difficulties are:

1. Sufficient rain may fall to germinate the seeds, but not enough to provide moisture for the young plant. If a dry warm period follows such a light rain, the seed may be wasted. Nature provides a great excess, so this does not matter, but the farmer whose crop is started by a light rain and is dried off by a hot dry period must sow again, thus suffering a double loss in seed and labour. The farmer is, however, always subject to similar troubles.

2. If the good rains come early the crops come on with great rapidity and begin to mature too early, being then liable to be caught by spring frosts, which, although not common, sometimes do much damage to early crops. Early varieties, which it is necessary to grow where the seasons are short, suffer most. This difficulty can be controlled by the farmer who has sheep, or who can buy them. There is much to be said for and against feeding off crops with sheep in dry districts, but experience appears to have thoroughly demonstrated its value in the case of crops which threaten to mature too soon.

MANURES AND FERTILISERS.

THE terms manure and fertiliser are used interchangeably by farmers and others throughout Australia, and there does not appear to be sufficient reason to attempt to change the custom. If a distinction were made, the word manure would apply to natural substances, as farmyard manure, which supply all or most of the plant foods required by crops. The term fertiliser would mean such articles as superphosphate, sulphate of potash and nitrate of soda, which each supply one chief substance required for the nutrition of plants. Any attempt to classify all the materials used as manures and fertilisers under the two headings would end in confusion. Such terms as artificial manures, artificial fertilisers, commercial fertilisers, are unnecessary and often misleading.

The practice of using the excrements of animals to fertilise the soil is older than history; but the explanation of their effect is quite modern, dating only from last century. We do not yet fully understand, for, as A. D. Hall says: "There are many beliefs and practices more or less current among farmers which science has neither verified nor disproved." Investigation is continually going on and every year new discoveries are made. We have briefly studied how the plant grows, and have discussed the factors which together constitute a fertile soil. We have seen that actual plant food is only one of these factors. Physical condition is as important as the chemical composition of soil. Only a very small proportion of a plant is ash, but apart from water this ash comprises all that the plant obtains from the soil. It has been shown that water is the all-important soil constituent. It is the medium by which plants obtain mineral matter and combined nitrogen from the soil.

Of the plant foods obtained from the soil in solution only three are at all likely to be deficient in any ordinary soil. Under most Australian conditions these, in the order of their importance, are phosphoric acid, potash and nitrogen. In some cases lime must be added to the list. In English and American books on agriculture, nitrogen is always placed first, because the growth made by a plant, other things being favourable, is dependent on the nitrogen supply, and, in the Northern Hemisphere, it is usually the most likely to be deficient. Nitrogen is equally important for plants here as on the other side of the world, but experience has proved that in the wheat areas of all the States, phosphoric acid is the plant food most likely to be lacking. It is the first to be exhausted in our virgin lands, and crops respond to its application more than to that of any other. So much is this the case that when a wheat grower speaks of fertiliser or manure he almost invariably means some form of phosphatic manure, usually superphosphate.

We shall therefore discuss phosphatic manures or fertilisers first.

Phosphatic manures or fertilisers. There are four types of phosphatic manure in more or less common use in Australia. These are:

1. Superphosphate.
2. Basic slag, or Thomas phosphate.
3. Bone dust.
4. Guano.

Although bone dust and guano also contain nitrogen, the object of applying all these fertilisers is to supply phosphoric acid, and their value chiefly depends:

1. On the percentage of this substance which they contain.
2. On its availability, or the way it is combined with the other substances in the fertiliser.
3. On the soil conditions and nature of the crop.

The Fertiliser Acts of the various States are not quite uniform, but usually make it compulsory that a seller of phosphatic manure shall supply the buyer with a certificate of analysis stating the percentage of water of soluble phosphoric acid, citrate soluble phosphoric acid, and acid soluble (often termed insoluble) phosphoric acid it contains. In England, the law is slightly different, and provides for the seller giving an invoice stating the percentage of soluble phosphates. In Australia, it is the custom of sellers of superphosphate, when making sales and in marking the bags, to follow the English practice, because, expressed in this way, the figures are bigger. This leads to confusion in the mind of the farmer, and it is necessary to try and make the meaning of these terms as clear as possible.

Phosphoric acid. When a piece of ordinary stick phosphorus is burned it gives rise to dense white fumes, which are a combination of two parts of phosphorus with five parts of oxygen, the chemical formula being P_2O_5. This is what the analyst refers to as "phosphoric acid." It does not exist in such a state in nature; but is found in combination with various other substances.

Phosphate of lime. So far as manures are concerned, the combination is practically always with lime, and is known as phosphate of lime. The typical phosphate of lime, which is the starting point of phosphatic manures, is a combination of one part of phosphoric acid (P_2O_5) with three parts of lime (CaO). Add together P_2O_5 and $3CaO$ and we get $Ca_3P_2O_8$, which is called tri-calcium phosphate, or commonly simply phosphate of lime.

This tri-calcium phosphate is found in various forms. The most familiar is bones, which contain from 43 to 51 per cent. of phosphate of lime. Certain minerals, known as phosphatic rock, contain varying proportions, up to over 80 per cent., of phosphate of lime.

In every 310 parts of phosphate of lime there are 142 parts of phosphoric acid. If we divided the 310 by 142 we get 2.18; and, if we divide any percentage of phosphate of lime by this number, we obtain the percentage of phosphoric acid. If, on the other hand, we multiply the percentage of phosphoric acid by 2.18 we find its equivalent in phosphate of lime. If a manure dealer offers for sale a fertiliser which he guarantees to contain 43.6 per cent. phosphate of lime, it is the same as if he said it contained 20 per cent. of phosphoric acid. The reason for a salesman using the bigger number is apparent, but it will become clearer later on.

Bones as manure. Bones were the first form of phosphatic manure to be used in agriculture, and for a long time they were the only form. It is impossible to say when they were first used, but they were in common use in some parts of England in the latter end of the eighteenth century; and, early in the nineteenth, bones began to be imported from the Continent of Europe. For use, they were broken up into half and quarter inch fragments. Bones are still one of the most valuable forms of phosphatic manure, and are prepared by being first steamed and then ground as finely as possible and sold as bone dust, bone meal, bone flour, etc.

Raw bones are not uniform in composition. The bones of different animals vary. Even in the same animal, the solid heavy bones differ from the light ones. Bones used in the manufacture of bone dust also vary according to the treatment they have received. For these reasons the composition of bone dust is variable. Raw bones consist of a mineral framework of tri-calcium phosphate, with some carbonate of lime. This framework comprises about half of the weight of the bone, the rest being water, fat and nitrogenous compounds forming cartilage. If a bone be burned the mineral matter alone is left. If it be soaked in nitric acid the animal or organic matter is left. This is an experiment every student should try.

In making bone dust or bone meal, the bones are first steamed under pressure in special vats to extract the fat. They are then dried and ground as finely as possible. Fine grinding is, however, difficult, unless the steaming is done at a pressure of over 60 lbs. to the square inch to extract the glue. Such highly steamed bones make a fine bone meal with up to 60 per cent. of tri-calcium phosphate, but only from 1 to 1.5 per cent. of nitrogen. Ordinary pure bone meal, from which the fat only has been removed, should contain from 3½ to 5 per cent. of nitrogen, and from say 46 to over 50 per cent. of tri-calcium phosphate of lime (equivalent to, say, 21 to 22 per cent. of phosphoric acid).

Ground bone charcoal is used as a purifier in the manufacture of sugar, and is afterwards sold as a phosphatic fertiliser, under the name of bone black. The supply is limited and the composition variable. It may contain from 32 to 36 per cent. of phosphoric acid and a little nitrogen, and is a slow acting manure.

When bones are burned the organic matter, including the nitrogen, is lost, but all the phosphate of lime is left in a form which can readily be crushed. It is a wasteful way of treating bones, but it is of value in the home garden. Bone ash may contain from 27 to 36 per cent. of phosphoric acid in what is called the insoluble form. It is valuable material to add to the garden compost heap where the fermentation promotes the availability of the phosphoric acid.

Mineral phosphates. In various parts of the world there are deposits of mineral phosphate of lime. One form is a crystalline rock called apatite, another consists of nodules of varying sizes called coprolites. Others are in the form of beds of material, in appearance much like the common travertine limestone, so common in South Australia. They were once probably beds of soft limestone, but the carbonic acid has been more or less replaced by phosphoric acid derived from guano. The percentage of phosphoric acid, on which the value of the rock depends, varies greatly. Among the richest are the deposits on Ocean Island in the Pacific, east of New Guinea, and Christmas Island, 190 miles south of Java; and it is from these places that Australia draws most of her supply of phosphatic rock. Some of these beds are very rich, containing about 40 per cent. phosphoric acid, or over 80 per cent. of phosphate of lime. Deposits of low grade phosphate of lime have been found, and are worked in several parts of South Australia; and there are extensive deposits of phosphate of uncertain composition in Western Australia which are likely to prove of considerable value under special treatment.

The phosphate of lime in rock phosphate is insoluble in pure water and weak acids, and the phosphoric acid is therefore not available for plants. If the rock be ground to a very fine powder and applied to moist soils, the phosphoric acid does become slowly available, especially in acid soils, and the use of very finely ground rock phosphate is increasing in America, and has been tested with good results in New Zealand. The fact is mentioned, but only careful extended experiment will show whether or not ground raw phosphate is of practical value in some of the wet acid soils of Australia. For our wheat lands, phosphates, not readily soluble, should not be purchased, because very often no appreciable immediate result is seen from their application.

Superphosphate. The discovery that treating bones with sulphuric acid renders the phosphate of lime soluble, so that the phosphoric acid is at once available as plant food, was announced by Baron von Liebig in 1840; but Mr. (afterwards Sir) John Bennet Lawes had been at work in the matter previously, and in 1842 he was granted a patent for making superphosphate from phosphatic rock. The commencement of the use of this important fertiliser is therefore within the memory of old men of to-day.

Bone superphosphate. Bone superphosphate is made by treating ground bones with sulphuric acid. This is an unnecessary and wasteful process, because ground bones are a costly material having a special value of their own, and when treated the soluble phosphate of lime is, as far as can be tested, identical with the same material made from the cheaper rock phosphate. A mixture of mineral superphosphate and bone dust is often useful, but there does not appear to be any sound reason for buying the more costly bone superphosphate.

Mineral superphosphate. Ordinary superphosphate, or mineral superphosphate, is manufactured from one of the forms of rock phosphate of lime, and its richness and value, when well made, depends on the quality of the rock used.

Simply stated, the rock phosphate of lime is first crushed, then ground to a fine powder. A weighed amount of this fine powdered tri-calcium phosphate is put into a mechanical mixer, an exactly calculated quantity of dilute sulphuric acid is poured in and the two are rapidly mixed. The result is a hot, sloppy, sludge-like material, which is dropped or emptied into a special chamber, where it solidifies as the chemical combinations are completed, and is then superphosphate. The quantities of raw phosphate and acid are so nicely calculated that the resulting superphosphate is a friable material, easily crushed and dry enough to run through a fertiliser drill.

In calculating the quantity of sulphuric acid to use, a little of the tri-calcium phosphate is left undecomposed, in order to secure the necessary dryness, because an excess of acid attracts moisture and produces a poor mechanical condition, besides being prejudicial in other ways. A free running character is a most important quality from the farmer's point of view.

Reverted, or citrate soluble phosphate. The phosphate of lime left unchanged will always slowly combine with some of the acid phosphate to form an intermediate stage between the original tri-calcium phosphate and the water-soluble mono-calcium phosphate. This intermediate form is known as reverted phosphate, di-calcium phosphate, or citrate soluble phosphate, because, although it is insoluble in water, it is soluble in ammonium citrate.

Superphosphate is valued practically for its percentage of water-soluble or mono-calcium phosphate, and this, to comply with the Fertiliser Laws, must be stated in its equivalent of phosphoric acid. All samples, however, contain some reverted, or di-calcium phosphate, and most also have a percentage of acid soluble, or tri-calcium phosphate. The best Australian manufacturers aim at producing what they call a 17-1-2 superphosphate, which means:

17 per cent. water soluble phosphoric acid,
1 per cent. citrate soluble phosphoric acid.
2 per cent. acid soluble phosphoric acid.

Three forms of phosphates. The three forms we have mentioned, in which the phosphoric acid is combined in lime, may be illustrated in this way:

1. *Acid soluble or tri-calcium phosphate:*

$$\left.\begin{array}{l}\text{Lime}\\ \text{Lime}\\ \text{Lime}\end{array}\right\}\text{ Phosphoric acid.}$$

In this there are 142 parts by weight of phosphoric acid, combined with 168 parts of lime. It is insoluble in water, and is often called "insoluble" phosphate of lime, a term which should be dropped in favour of acid soluble.

2. *Mono-calcium phosphate.* When sulphuric acid is added to the above tri-calcium phosphate an interchange takes place. The sulphuric acid robs the tri-calcium phosphate of two parts of the lime and forms calcium sulphate or gypsum, while two parts of water take the place of the lime so taken away. We thus have:

$$\left.\begin{array}{l}\text{Lime}\\ \text{Water}\\ \text{Water}\end{array}\right\}\text{ Phosphoric acid,}$$

together with gypsum or calcium sulphate.

In this there are 142 parts of phosphoric acid combined with 56 parts of lime. The other 112 parts of lime are now combined with the sulphuric acid, forming gypsum. This is what puzzles the farmer. He cannot understand why he cannot get his phosphoric acid without so much useless gypsum. He has to buy 100 lbs. of superphosphate to get about 17 lbs. of phosphoric acid. The manufacturer can separate much of the useless gypsum and make what is known as concentrated super or double super, containing as high as 40 per cent. of phosphoric acid, but it is not considered economical to do so.

Roughly, it takes about one ton of dilute sulphuric acid and one ton of tri-calcium phosphatic rock to make two tons of superphosphate. If, therefore, the rock phosphate contained 36 per cent. of phosphoric acid, the superphosphate would only contain about 18 per cent. phosphoric acid. These figures are only approximate, but they indicate how much sulphuric acid is used in making the large quantity of superphosphate used in the various States.

The chemist explains the formation of superphosphate by this equation :

$$Ca_3P_2O_8 + 2H_2SO_4 + 4H_2O$$
$$= CaH_4P_2O_8 + 2(CaSO_4 2H_2O.)$$

3. *Reverted, citrate soluble, or di-calcium phosphate.* Soluble mono-calcium phosphate is always ready to go back to its original insoluble tri-calcic form when lime is available. Intermediate between the two is di-calcium phosphate, in which there are two parts of lime to one of phosphoric acid, thus :

$$\left.\begin{array}{l}\text{Lime}\\ \text{Lime}\\ \text{Water}\end{array}\right\}\text{ Phosphoric acid.}$$

In this, for every 142 parts of phosphoric acid there are 112 parts of lime. Soluble phosphate, when applied to the land, quickly goes back to this form, but is distributed in such a finely divided state among the soil particles that it can be made use of by plants. This will be referred to again.

The following table of factors is useful :

To find the equivalent of tri-calcium phosphate in a given percentage of mono-calcium phosphate, multiply the percentage of mono-calcium phosphate by 1.33.

To find the equivalent of tri-calcium phosphate in a given percentage of di-calcium phosphate, multiply the latter by 1.14.

To find the equivalent of mono-calcium phosphate for a given percentage of phosphoric acid, multiply by 1.65.

To find the equivalent of di-calcium phosphate for a given percentage of phosphoric acid, multiply by 1.91.

To find the equivalent of tri-calcium phosphate for a given percentage of phosphoric acid, multiply by 2.18.

Basic slag, or Thomas phosphate. Many iron ores contain phosphorus, and the cast iron made from them is useless for making steel until the phosphorus is removed. This is done by a process invented by Messrs. Thomas and Gilchrist. By their process the furnace used for converting cast iron to steel is lined with lime, and lime and magnesia are added to the iron to form a base, with which the phosphoric acid from the molten iron will readily combine, leaving the iron free. The resulting slag contains varying quantities of phosphoric acid from 12 up to 23 per cent. Its use as a fertiliser dates from about 1885. The basic slag, or Thomas phosphate, sold as a phosphatic fertiliser is this slag, ground so that 80 per cent. passes through a sieve having 100 meshes to the inch, or 10,000 holes to the square inch. Fresh basic slag contains from 2 to 10 per cent. of quick lime, but rarely over 6 per cent., and varying quantities of iron, magnesia and other substances. An average sample will contain 14 to 17 per cent. of phosphoric acid. It should always be purchased on its percentage of phosphoric acid. Its value largely depends on the fineness of the grinding.

The exact nature of the combination of phosphoric acid and lime in Thomas phosphate appears to be uncertain, but it is usually stated to be four parts of lime to one of phosphoric acid. All that is of importance to the farmer is the fact that it is readily soluble in weak acids such as are found in the soil, and is known as citric soluble, *not citrate.* This little distinction should be noted. As a fertiliser, it is considered equivalent to the reverted or citrate soluble phosphoric acid in superphosphate. It is not suitable for dry country, but has special value, under moist conditions, for acid soils or for soils deficient in lime. It is valuable as a top dressing for pasture where there is moisture enough, and it is a good fertiliser for leguminous crops.

Guano. Guano is a term covering a wide range of fertilising substances. It is not of very great importance at the present time in Australia, except perhaps in Western Australia, where there are still considerable deposits of phosphatic guano obtained from the Abrolhos and other islands of the coast, and from the extensive series of limestone caves along the west coast between Geraldton and Perth. Deposits of phosphatic material have also been or are still worked from various islands off the coast or other parts of Australia, and from caves in South Australia and Queensland. The value of these guanos is often overstated by the sellers, the fact being ignored that the phosphoric acid they contain is chiefly in the tri-calcic or acid soluble form. They contain varying percentages of organic nitrogen in a slowly available form, and have their greatest value when used in light soils inclined to be leachy.

Peruvian guano is not of very great importance in Australia. The only form in the market is Ohlendorf's dissolved Peruvian guano, which has been specially treated to make the phosphoric acid available. The composition is standardised by the addition of other ingredients. It is a readily available "complete" fertiliser, somewhat expensive, but has a special value for some purposes in the vegetable garden.

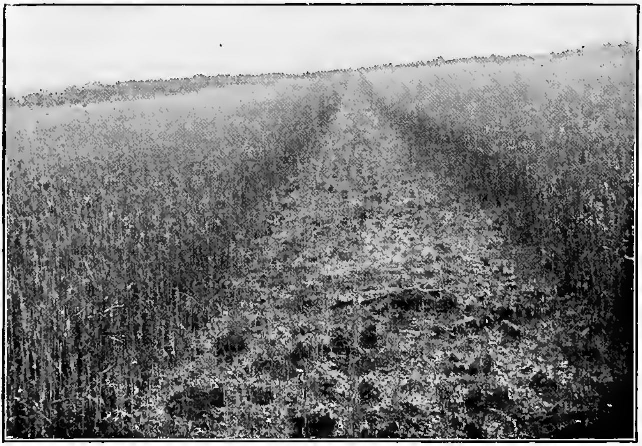
The use or function of phosphates. Hall says: "Just as nitrogen delays maturity by promoting growth, phosphoric acid has an opposite effect, it is in some way closely bound up with grain formation, being always found in greater proportions in the reproductive parts of the plant than elsewhere." The same authority also states that "Phosphoric acid increases the proportion of grain to straw, and decreases the nitrogen content of the grain," and in another place "the action of phosphoric acid on the plant is not confined to its ripening effect, it stimulates the early development of the young seedling to a remarkable extent. Both in the field and the pot experiments, the phosphoric acid has a great effect in promoting the formation of adventitious buds, so leading to the tillering of the plant." He expresses the opinion that "there can be little doubt but that this explains why a phosphatic manuring has such a valuable effect in establishing the plant even if the gross yield is not ultimately advanced."

"It may also go to explain the extraordinary results of quite small dressings of phosphoric acid upon soils in Southern Australia, where a manuring with half a cwt. per acre or even less, of superphosphate has been found to sometimes double the yield of cereals. On analysis the soils are not rich, but they show no such signal deficiency in phosphoric acid as would account for the action of the manure.

"It seems much more likely that in a semi-arid country, where the whole success of the crop depends on the roots getting quickly down to the cooler and moister subsoil, the stimulating action of the phosphoric acid upon the young roots becomes of the utmost value." Phosphoric acid enables the wheat plant to mature with a smaller supply of water than is otherwise required. This fact is important in connection with its use in the drier wheat areas. It also appears to exert a beneficial influence on micro-organisms of the soil which render nitrogen available.

The results following the application of phosphates to wheat lands have become so familiar that they do not attract the same notice as they did ten or twelve years ago, and striking examples are not so common as they were when the use of superphosphate was becoming general from 1896 to 1900: but some may be seen in all wheat growing districts every year. From a mass of notes on the subject, extending over fourteen seasons in four States, two examples will be given, because photographs are available for illustrations.

Influence of super on wheat. In November, 1905, near County Peak, Western Australia, the writer took a photograph illustrating the remarkable effect which a small dressing of superphosphate often has in Australia. The field was twenty-five acres in extent, and the soil was admittedly of a poor gritty nature, derived from granite, and in its original state was covered with scrub, with no large trees. The field was carrying its first crop. A bushel to the acre of seed wheat was drilled in during the second week in May, together with 56 lbs. of superphosphate. When the seed was being drilled in, the manure attachment failed to act through the greater part of one trip of the drill across the field. When the crop was inspected the wheat was nearly ripe, and the strip of unfertilised land looked like a roadway across the field, so great was the difference in the development of the plants. The photograph illustrates the contrast fairly well. In the presence of three farmer witnesses we gathered average samples of the product, from the fertilised and the unfertilised land, and they were afterwards photographed to show the contrast. On the manured land the wheat had stooled fairly well, grown well, and stood between 3 and 4 ft. tall, with nice well-developed heavy heads. The crop was estimated to yield from 16 to 20 bushels per acre. The plants on the unmanured strips were weak and spindly, generally only one small stem to a seed, and the heads were small and poorly developed. The contrast was remarkable.

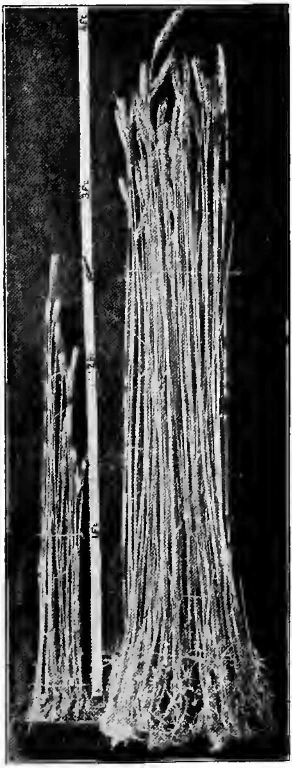


Effect of Phosphate.

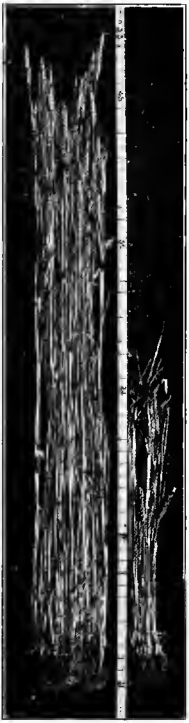
The centre is a strip the width of the drill. 56 lbs. per acre was being applied with a combined drill, but on this strip the fertiliser mechanism failed to act.

Effect of small dressings of superphosphate. When inspecting the crops in South Cowcowing, Western

Australia, at the end of September, 1910, the writer was shown a remarkable example, illustrating the effect of a small quantity of superphosphate on the wheat crop. The field under notice comprised 200



THE PRODUCT OF AN EQUAL NUMBER OF GRAINS OF WHEAT WITH AND WITHOUT PHOSPHATE.



THE EFFECT OF PHOSPHATES.
Cowcowing, Mr. Jones' farm,
Western Australia.

acres of land, and was cleared of timber in the summer of 1907-8.

In April, 1908, the surface was scratched with a spring tooth cultivator, and wheat was drilled in without fertiliser. The result was a very fair crop of hay, but the owner has no record of the actual yield. In April, 1909, the soil was again scratched with a cultivator, and drilled with seed wheat and 25 lbs. of superphosphate. The crop varied in different parts of the field from 18 to 27 bushels to the acre. In April, 1910, the paddock was again sown, without ploughing, being merely worked with a cultivator and drilled with seed and 30 lbs. of superphosphate. During the operation of drilling one strip, the mechanism of the fertiliser attachment worked badly. The seed was sown as on the rest of the field, but only a little superphosphate was dropped here and there. Where the superphosphate was applied, the crop on this strip was the same as the average of the field, but where the fertiliser missed, the plants were miserable, puny, and only from 12 to 20 ins. high, whereas the rest of the field was over 4 feet. In the presence of four witnesses, careful average samples were taken from the fertilised and unfertilised land. Twelve plants of each are shown in the illustration. The appearance of the crop indicated a yield of quite 20 bushels to the acre. It will be noted that this was the third crop from virgin land without ploughing the ground. It is probable that the crop on the land at the time of inspection was removing about 15 lbs. of phosphoric acid to the acre, whereas the 30 lbs. of superphosphate supplied with the seed would only supply about 5½ lbs. Yet the absence of this small quantity made the remarkable difference in the crop. The only explanation that can be given is that the small dressing of phosphoric acid enabled the plant to form a healthy root system, so that it was able to secure the rest of its supplies from the reserves held by the soil; but it may be that the wonderful result is due to some unknown and unsuspected effect on soil bacteria, and on the reserve supply of potash in the soil.

Action of various phosphatic manures. Mr. A. D. Hall says: "In considering the action of the various phosphatic manures in the field, the most important factor to be taken into account is the soil, for the relative value of the fertilisers will change entirely with different types of soil. For example, the choice between superphosphate and basic slag or bone meal, as a phosphatic manure, must be determined, not by their comparative solubility, but by the amount of calcium carbonate in and the wetness or dryness of the soil to which the fertiliser is to be applied. A very large number of experiments have been made to institute a comparison between these fertilisers, but without resulting in any very general information, just because the question is really settled by those soil factors which are generally unrecorded. On certain soils one or other of these manures will always give the best results; on other soils their effects may be so much alike that the choice between them can be settled by price alone or by any consideration of convenience that may enter.

"On nearly all normal soils superphosphate is the most effective phosphatic fertiliser when equal amounts of phosphoric acid are compared. The exceptions are the light sands and gravels, very deficient in carbonate of lime, peaty soils where the humus is of the sour type, and all other soils that have developed an acid reaction."

Why superphosphate is so effective. Wherever the conditions are favourable, there seems little doubt that superphosphate is the best form of phosphatic manure to use, and in the wheat areas it is the only one to be depended on. The reason is simple. When the superphosphate is applied to the soil, the first rains dissolve it and the solution is carried through the soil, to be rapidly re-precipitated on the soil particles with which it comes in contact. If carbonate of lime is present, as it should be in well-constituted soils, it takes the chief part in the reaction, di-calcium phosphate being formed. Clay also acts as a base, and the result is that every tiny soil particle with which the solution comes into contact receives its share of phosphoric acid. It is no longer soluble in pure water, but it is available for the root action of the plants. It is the wonderfully fine state of subdivision and the wide distribution which gives it its value. It does not appear to have ever been definitely stated, but it would seem that in farm practice plants obtain their supplies from the citrate soluble or citric soluble forms of phosphoric acid.

Phosphoric acid not lost. The Rothamsted experiments prove positively that in well-constituted soils the soluble phosphoric acid of superphosphate is not washed away, for so rapid is the precipitation that practically none is washed into the subsoil. It remains in the surface soil in a finely divided form, which is readily available under the action of weak acids, such as the natural solution of carbon dioxide occurring in the soil. The all-important fact in connection with the application of phosphatic fertilisers is to get them thoroughly disseminated through the soil. "Fine grinding and early application are the two great factors in making phosphatic manures available." In the use of superphosphate the importance of having sufficient carbonate of lime in the soil cannot be too strongly enforced. In the wheat growing areas of Australia this is usually the case.

Roseworthy Agricultural College farm seems to afford the most complete example known to the writer, of the increasingly good results following the consistent applications of heavy dressings of phosphatic fertilisers, over a fairly long period of years, to land naturally very rich in carbonate of lime, and an average rainfall of between 17 and 18 inches, ranging from about 13 to 27 inches. Commenced by Professor Custance in the early eighties, the practice was continued and emphasised by Professor Lowrie, and under Professor Perkins the policy has been carried on with zeal, and the results, recorded with that gentleman's customary methodical accuracy, in reports, which, for comprehensive detail, are unique on this side of the world, promising in years to come to be as valuable for corresponding conditions in Australia as the famous Rothamsted experiments are in England.

On heavy clays, especially where lime is deficient and moisture abundant, and on peaty soils basic slag has special value. It should be applied early, and be given plenty of time to become distributed through the soil. "The choice between basic slag and superphosphate should in the main be determined by the soil." This, of course, is presupposing sufficient moisture. Hall says, and Australian experience supports the statement, "The more calcareous and loamy the soil the more effective is superphosphate, but heavy soils and land, poor in carbonate of lime, respond better to basic slag, and on wet sour soils no other phosphatic manure should be used."

On light sandy soils the less soluble forms of phosphatic manures should be used. It is on these soils that bone dust, which should be finely ground, is specially valuable. In many cases it is advisable when carbonate of lime is deficient to mix superphosphate and bone dust. The proportions will vary from equal quantities to two to one either way. Hall advises that super and basic slag even may at times be mixed with advantage under such circumstances in order to obtain a neutral manure. In making these mixtures they should be left in a heap for a short time for the reactions to take place, then broken down to a fine powder for application to the soil. He says: "This is probably the cheapest way of obtaining an easily available neutral phosphate for use on light arable land where superphosphate is unsuitable because of the lack of carbonate of lime." There is not wanting evidence to show that the above advice is applicable to special conditions in each of the Australian States, but nowhere more so than on the light sandy soils of the coast districts of Western Australia.

Importance of nitrogen. If we take up any book on manures, written in Britain or America, we find the first place given to nitrogen. Aikman says in his *Manures and Manuring*, "Of manurial ingredients nitrogen is by far the most important, and on the presence and character of the nitrogen it contains the fertility of the soil may be said to be the most largely dependent."

Hall, in his most recent standard book, *Fertilisers and Manures*, says: "Among the elements of the nutrition of the plant the first place must be given to nitrogen. Not only does it cost more per pound, but as a fertiliser, applied to ordinary soils, it seems to have a more direct and immediate effect upon the plant."

The nutrition of plants is the same in Australia as in the old world, and European trained agriculturists, brought out to teach the science of agriculture, have usually strongly urged the importance of nitrogenous manures until they learned by experience that for wheat production, in what are recognised as the wheat growing areas of Australia, nitrogenous fertilisers, as a rule, show no results at all, and in some cases are found to be positively harmful. In vegetable growing and intense culture in the cooler wetter districts of the various States the importance of nitrogenous manures is recognised, but even under such conditions not usually to the same extent as in

England. In the cooler wetter farming districts the value of top dressing cereal crops in early spring with a nitrogenous fertiliser is well known to the more advanced farmers, but the practice is not general.

What is at present known, or supposed, as to the reason why nitrogenous fertilisers are not necessary over vast areas of Australia is summarised in another place. Combined nitrogen is equally important for plant growth here as in Britain or America, and, if we so far find no need to supply it in the form of fertilisers, we have to thank nature's mysterious processes for the saving. Our climate has some drawbacks, especially in respect to the irregularity of the rainfall in many places and the intense dry heat. The nitrogen supply is one of the equally pronounced beneficial features. What little we have to say about nitrogenous fertilisers will apply to the cooler wetter districts and to land used for intense culture, such as market gardening and the raising of quick growing succulent crops. Other conditions being favourable, the development of plants is proportional to the supply of combined nitrogen, and if that is not naturally available it must be added.

Chief nitrogenous fertilisers. The chief nitrogenous fertilisers used or available in Australia are:

1. Nitrate of soda.
2. Sulphate of ammonia.
3. The recently introduced products of electric furnaces, such as nitrate of lime, calcium cyanamide, or nitrolim.
4. Organic manures, such as dried blood, bone manure, farmyard manure, etc.

The first three may be grouped together as quick-acting nitrogenous fertilisers.

Nitrate of soda. Nitrate of soda is obtained from the nitrate beds of Chili, and is sometimes called Chili saltpetre, the output being over one and a quarter million tons per year. Its export to England dates back to about 1830. As manufactured for export, the nitrate of soda of commerce contains about 95 per cent. pure sodium nitrate, of which about 15½ per cent. is nitrogen in the form most readily available for the use of plants. It is very soluble in water, and is easily leached out of the soil. For this reason it is best used as a top dressing, but, as it will scorch or destroy green tissue, care should be exercised not to allow it to come in contact with the foliage of plants, unless it can be quickly and completely washed off.

Nitrate of soda may be mixed with other fertilisers except superphosphate, the acid of which gradually liberates nitric acid, the valuable plant food constituent of the fertiliser. It may be mixed with superphosphate if applied to the land immediately, but separate applications are preferable.

Nitrate of soda exercises two indirect influences on the soil; one beneficial and the other injurious. The nitric acid is quickly made use of by the growing plant, and the soda left behind acts on the insoluble potash compounds in the soil and helps to render them available. On the other hand, the free use of nitrate of soda on heavy soils has a prejudicial influence on its texture, tending to make it sticky when wet and to cake hard when dry. We do not know of any trouble in this connection having yet arisen in Australia.

As a fertiliser, special value of nitrate of soda is its immediate availability. It is for this reason that it exercises such a marked effect on quick growing vegetables, and in a few days a top dressing will change the colour of a wheat, oat or barley crop, after a cold, wet winter, from a sickly yellow to healthy green. In the wet, colder districts of Australia the use of this or other quick acting nitrogenous fertiliser for top dressing hay crops at the end of winter should be encouraged. If farmers would only try the effect of such a top dressing on a portion of a sickly looking yellow crop in August they would realise its practical value.

Sulphate of ammonia. In Australia, sulphate of ammonia is practically all obtained as a bye-product from the gas and coke works. Pure sulphate of ammonia contains 21.2 per cent. of nitrogen, but the commercial article usually has about 20 per cent. If mixed with lime it gives off ammonia gas, and it should therefore never be mixed with lime or Thomas phosphate. No change takes place where it is mixed with superphosphate. It is the nitrogenous fertiliser chiefly used by manure manufacturers in making "complete" fertilisers.

For most practical purposes sulphate of ammonia is equally effective as a fertiliser as is nitrate of soda, and, as a given weight contains more nitrogen, it is more costly per ton to buy. It is now known that many plants can use nitrogen in the form of ammonia, but apart from this the process of nitrification in suitable soils is so rapid that the effect of a dressing of sulphate of ammonia is seen almost at once. It may be used for top dressing hay crops in spring in place of nitrate of soda. Mr. A. D. Hall shows that one effect of the free use of sulphate of ammonia is to rapidly remove carbonate of lime from the soil, forming ammonium carbonate and calcium sulphate, and for this reason it is not a desirable fertiliser for soils deficient in lime. He recommends the use of a mixture of nitrate of soda and sulphate of ammonia in order that the after influence of the one may neutralise that of the other. They should only be mixed just prior to being used.

Nitrate of lime, etc. These new nitrogenous fertilisers are hardly yet on the Australian market. European experience shows the nitrogen they contain to be about equal in its effect to sulphate of ammonia. The writer has experimented with nitrate of lime as a top dressing, and the results corresponded with English tests.

Organic nitrogen. The nitrogen in organic substances has first to be broken down by soil bacteria before it is available as plant food. For this reason the nitrogen in bone dust, dried blood, and organic manures is slow acting. When the soil is leachy and the crop holds possession of the ground for a considerable time this is an advantage. Bone dust is, however, a costly form in which to supply nitrogen. Organic manures should be applied to the soil in time to allow of the natural changes taking place. Their beneficial influence on the physical condition of the soil is in their favour, and this partly explains their popularity with gardeners.

Function of nitrogenous fertilisers. A too liberal supply of nitrogen, by forcing vegetative growth, is often prejudicial to crops. Many an amateur gardener has ruined his turnip crop by trying to grow it in soil too rich in nitrogen. He is at first pleased with the luxuriant growth of tops, and then wonders why the turnips are not correspondingly fine. Onion growers sometimes fail from the same cause, and ask why their onions are all tops and do not bulb well. Hay growers appreciate a liberal supply of nitrogen, except when it causes their crops to lodge, but the wheat grower who admires his tall luxuriant crop, and finds that the yield is not in proportion, not infrequently may find the cause in the too rich supply of nitrogen associated either with a lack of phosphoric acid or potash, or a too rapid closing in of the season, preventing the final stages of development. There is much to learn in this connection. An excess of nitrogen is favourable to the development of fungus diseases such as red rust, other conditions being of course favourable, because an excess of nitrogen tends to produce a late crop, with much succulent foliage.

Fertilisers supplying potash. Up to 1861, when the Stassfurt mines were opened up, the chief source of potash was wood ashes, saltpetre or nitre of potash from India, and a little sulphate of potash obtained by burning kelp. With the opening of the Stassfurt mines the use of potash fertilisers grew rapidly, and the output is now enormous.

Four forms of potash fertilisers from Stassfurt are on sale in Australia. These are sulphate of potash, muriate (or chloride) of potash, 30 per cent. potash manure, and kainit, which is a crude mixture of common salt, salts of magnesia and potash. As sold in Australia, sulphate of potash, which is the form more generally used, contains about 50 per cent. of pure potash; muriate, about 58 or 60 per cent. The Fertiliser Acts require that they shall be sold with a guarantee of the actual percentage of potash they contain, and purchasers of these as of other fertilisers should insist on this guarantee at the time the purchase is made, and see that the certificate supplied with the invoice agrees with the guarantee.

It should be explained that what the analyst calls potash is potassium oxide (K_2O), a compound which does not occur in that form in nature, but is a convenient and customary means of comparison.

Influence of potash fertilisers. Apart from market gardens, potato growing and orchards, the application of potash fertilisers in Australia has been so small that it is impossible to speak with any degree of certainty as to the present need for their use. If one thing more than another must be impressed on the farmer, in connection with the use of manures, it is the fact that only actual experiment will show whether or not any particular fertiliser is necessary and profitable. In connection with wheat growing the evidence indicates that the use of potash fertilisers is not so far profitable. At the same time the experiments carried out in New South Wales on thirty-four farms in various parts of the wheat growing district in 1909 showed that while the use of potash made little or no difference in the appearance of the crop, the yields were sufficiently increased to make the application profitable. The report, as published by the Agricultural Offices of the Potash Syndicate, Sydney, states that the average of the thirty-four experiments gave the following results.

1. No manure, 20 bus. 10 lb.
2. Superphosphate, 56 lbs. per acre, costing 2s. 3d., 22 bus. 36 lbs.
3. Superphosphate, 42 lbs. and sulphate of potash 14 lbs., costing 3s. 3d., 25 bus. 2 lbs.

The potash plots therefore give an average increase over the superphosphate of 2 bus. 26 lbs., at a cost of one shilling. One year's results are not enough on which to base an opinion, but they suggest further trial. The results from the "no manure" plots show that both soils and seasons were good.

For potato growing, potash is recognised as being generally a necessary ingredient of the fertiliser, except on specially rich potato land which produces heavy crops without any manure at all. In market gardening, potash is also necessary for the best results. Sulphate of potash is the form most generally used. The use of potash by fruit growers is on the increase, and experiments carried on during recent years show that the application is in many places profitable, as it has also proved to be in a number of instances for lucerne and peas. As potash is one of the important essentials for the development of plants, sooner or later it will probably become necessary to use potash fertilisers to maintain the supply in our wheat lands. It is, of course, bad business to spend money in buying and applying any manure which fails to give a profit, and all we suggest is that farmers should experiment. It is an accepted fact, based on careful experiment, that in all well constituted soils, potash fertilisers are not leached out of the ground. If not utilised by the crop they are there for future use, but no business man will spend money putting fertiliser in the soil merely for future use. It is better to put the money out at interest until the fertiliser is required.

Speaking of the importance of potash to plants, Hall says: "Enquiry goes to show that in some way potash is an essential part of the mechanism of the process of assimilation; when it is deficient the manufacture of carbohydrates, like starch, sugar and cellulose, is greatly reduced, and in practice it is the crops rich in carbohydrates which are most dependent upon a full supply of potash." This probably explains the value of potash for potatoes. Next to their effect upon carbohydrate making crops, the most striking action of potassic manures is their value in promoting the growth of clover and all leguminous crops.

On some of the Rothamsted plots, where nitrogen is applied and potash omitted, no leguminous plants are to be found. This applies even where there is an abundance of phosphoric acid. It is also found that on the potash-starved plots the grasses fail to a large extent to develop any seed. The thought occurs that the richness of our indigenous vegetation in genera and species of the natural order Leguminosæ may be associated with the good supply of potash in the soil.

Experiments also show that potash makes the plant more resistant to the attacks of fungoid diseases. If the soils, in good physical condition, produce good crops without potash it is waste of money to apply it. If they do not, the use of potash fertilisers should be tried.

Farmyard manure. Farmyard manure, which means the solid and liquid excrement of all classes of farm animals, together with the straw or other material used for bedding and to absorb the liquids, is valuable not only because of the plant food which it contains, but also because of the important influence on the physical condition of the soil and the humus it adds to the soil. Climatic and labour conditions in Australia are not favourable to the production of farmyard manure on a large scale. In no part is it necessary to house stock entirely, and in only a few places is partial housing needed or desirable from health considerations. Rugging cows is all that is necessary for dairy cattle, and the value of the manure as a rule is not sufficient to induce owners to stall feed even dairy cows and pay for the labour involved in the proper making and saving of the manure. Sheds open on the sheltered side are more healthy for horses than close stables, and the dryness of the climate during the greater part of the year reduces the litter required for bedding to small proportions.

Throughout the greater part of the farming district, and especially in the so-called wheat areas, it is not practicable to apply English and American ideas to the farmyard manure question. In the colder and wetter districts of the southern part of

Australia, from Cape Howe to the Leuwin, the conditions are more favourable for making farmyard manure, and its value is greater; but even here old world practices do not apply.

It is necessary to recognise these facts, and the additional one that farmyard manure, applied to wheat land in the dryer areas, will cause a vigorous development of straw and flag, and, as the season is not long enough for slow maturing, the crops "blight," and are ruined for grain. A heavy dressing will have that effect for several seasons. But when we have given full consideration to all the objections, it must be acknowledged by all who consider the question thoughtfully that the loss throughout Australia due to the lack of care in saving farmyard manure, and neglecting to use even the little that is made, amounts to a huge sum every year. We must be using up the reserves of organic matter in the soil, and although the problem is not serious at present, it should not be lost sight of.

The droppings of the animals out in the paddocks have their value there, and we do not desire to advocate any practice which labour conditions render unprofitable. But we do wish to urge with all the emphasis possible the importance of using organic manures to the fullest possible extent. The market gardener requires no such advice, neither do many hundreds of "old fashioned" farmers, especially in the districts with a good rainfall, but the average Australian has absolutely no conception of the truth expressed by the old English writer, who said, "Muck is the mother of money."

Farmyard manure in the wheat areas. In the wheat areas the amount of manure made on any farm, apart from that dropped in the paddocks, is comparatively small, and its direct plant food content not very great. For reasons stated it must not be used direct for the wheat crop, because it induces a too luxuriant growth ; but even light dressings have an important physical and biological effect on the soil. There are always special poor portions of a farm where it is highly profitable to go to considerable expense in giving a dressing of stable manure for the production of hay, and the sheep feed in the following season will be increased several fold. On thousands of farms the stable manure is considered a nuisance, and if it will blow or wash away so much the better. This is radically wrong. Whatever may be the precise explanation of the present abundant supply of nitrogen, it may be safely asserted that it is largely associated with the organic content of the soil. This must be maintained, and it is sinful waste of valuable materials to take no care of the farmyard manure. We have more than once laid down the principle that it is not good business to apply fertilisers merely to build up soil reserves when the money may be earning interest in other ways, but the maintenance and, under most conditions, the increase of the organic content of most Australian soils is a different matter, which should on no account be neglected. Farming is a business, and it is bad business to wantonly waste animal manures which no chemical fertilisers can replace.

The composition of farmyard manure. The excreta of animals varies greatly. The solid excrement may be considered as merely the undigested portions of the food consumed, with variable quantities of water. Rich concentrated foods produce rich manure, watery foods correspondingly poor dung. The character of animal droppings is also affected by various other considerations. Cows in milk and young growing animals take more from their food than do animals in the stages of fattening. Horse and sheep manures are dryer and richer than that of cows and pigs. Horse manure ferments more rapidly and produces greater heat than that of cows and pigs. We cannot consider this matter in the same way as the British farmer, because our feeding practices are so different.

The liquid excrement, or urine, represents the waste from the body of the portion of the food which has been digested, and in soluble forms has passed into the blood, being eventually excreted through the kidneys as urea, uric acid, etc. Herein is the great difference between the manurial value of dung and urine. Dung represents the undigested food, that is the portions which resisted the digestive ferments of the body, and are only slowly decomposed in the soil. The urine, on the other hand, consists of soluble compounds which are either available as plant food or require but slight changes to become so.

Urine decomposes very rapidly, and under ordinary conditions in most of our farmyards the larger part of the nitrogen is lost by being changed into ammonia, but "as long as the liquid containing the ammonium carbonate is protected from evaporation, no loss of nitrogen will result, but the more the surface is exposed to the air and the higher the temperature the greater will be the amount of ammonia passing off in a gaseous condition." The reader will see how favourable to such loss are the conditions usually found in Australian farms. Fortunately the loss is least important where the conditions are most favourable for its taking place. The more manure is stirred the greater the loss, and the more quickly it can be applied to the land and ploughed in, the greater is its fertilising value. In intense farming the value of farmyard manure is altogether in excess of its actual plant food content. This fact is most important where the supply is scanty. It adds organic matter to the soil, it increases its water holding capacity and it improves the physical conditions, which is quite as important as mere richness. We can add the necessary plant food in the form of chemical fertilisers, it is the biological and physical influence of farmyard manure which is of so great importance in Australian farming.

Analyses of farmyard manure. Even in England, where making and using farmyard manure plays such an important part in the yearly operations, it is only possible to give an approximate average composition. In Australia no figures are possible with regard to the actual plant food content of the material collected about farmyards and stables. Here and there a good manure pit is seen, but very rarely does this contain much of the liquid excrement.

The following figures, from Mr. A. D. Hall's *Fertilisers and Manures*, are included for reference:

Description.	Water.	Nitrogen.	Phosphoric Acid.	Potash.
1. Fresh long straw manure,	66·17	·544	·318	·673
2. No. 1 after rotting,	75·4	·597	·454	·491
3. Very old and short from mushroom bed,	53·14	·80	·63	·67
4. Fresh (French data),	75	·39	·18	·45
5. Rotten " "	75	·50	·26	·53
6. Very old " "	79	·58	·30	·50
7. Rothamsted average,	76	·64	·23	·32
8. Fresh liquid manure,	98·02	·044	·051	·355
9. Old " "	99·13	·026	·014	·22
10. London stable manure (straw),	70	·62	·48	·59

Money value of farmyard manure. It is quite impossible to accurately estimate the money value of farmyard manure on a basis of the plant food it contains. This is true in England, where it is made with care. It is doubly true in Australia, where the liquids are either not saved or are evaporated. Apart from this the plant food is in a different form to that in the soluble fertilisers. Probably it would be about right to value the nitrogen, phosphoric acid and potash in a ton of good manure from a city stable at from 8s. to 10s. But its chief value is its physical and biological effect on the soil. If the soil requires organic matter, stable manure is worth much more than the unit value of its contents. If the soil, on the other hand, is rich in organic matter and is sweet and mellow, stable manure may be of little benefit and be hardly worth the cost of applying it, but such cases are rare. There is always some portion of the farm where it is needed, and for vegetable growing it is invaluable, although it is not uncommon to find market gardeners absolutely wasting money over an excess of stable manure when fertilisers would be cheaper and give quicker and better results. A little knowledge of the principles of manuring, together with a little thoughtful experiment, would often save market gardeners big sums every year.

Green manuring. By green manuring is meant the growing of a crop for the purpose of ploughing it in to add organic matter to the soil and improve its physical condition. This practice is not at present applicable to large areas of wheat lands, but it is an important operation in orchard work, as well as on many farms where intense cultivation is carried on.

The ploughing of land carrying a growth of weeds is the most common form of green manuring in Australia, and as the weeds often consist partly of annual clovers and trefoils the value of this operation is nearly as effective and a great deal cheaper than growing a special crop. It is thoroughly good practice to sow peas, tares, burr trefoil or crimson clover seed in an orchard at the end of summer, at the same time applying a dressing of superphosphate and potash. Where stable manure is scarce it is a good practice to turn in a sod of clover and grass in preparing land for potatoes.

There is no question whatever that the problem of keeping the soil well supplied with organic matter in our wheat areas is as difficult as it is important. The following system is necessary for the conservation of moisture as well as for the convenience of cropping large areas, but it leads to the rapid exhaustion of the already too scanty supply of organic matter, and the problem of replacing it will have to be faced sooner or later. The practical difficulties in the way are great. We have already referred to the matter in our discussion on farmyard manure, and have seen that very little can be done in this way. The working conditions for growing special crops for green manure is as equally impracticable under present conditions. In the major portion of the wheat areas the growth of summer crops is quite out of the question. In districts where summer rains occur with sufficient regularity, the growth of cow peas on the fallows and feeding them off with sheep is a plan to be recommended, but the area in Australia where this can be done is comparatively small. The growth of summer crops cannot be relied upon in the northern and north-western part of Victoria, in the wheat areas of South Australia or in many parts of New South Wales, while in Western Australia they are quite impracticable except under irrigation.

The only solution of the problem at present appears to be the fertilising of the stubble land and the growth of any suitable green crop during the years of rotation when the land is not under wheat and turning in as much growth as possible when fallowing the land. This, of course, is burying green fodder which might be used for feeding sheep, which themselves are a great assistance in maintaining the supply of organic matter in the soil.

In advice on green manuring it is always recommended that a leguminous crop should be grown, but our nitrogen problem seems so perfectly simple, where there is a supply of organic matter in the soil, that the farmer need not trouble very much what kind of green manuring crop he grows as long as he can provide a supply of organic matter. As a matter of fact the introduced annual clovers and trefoils, which have spread over every agricultural district and grow luxuriantly wherever the ground is fertilised with phosphates, seems to largely answer the question. Possibly the common burr trefoil, sown before the first rains and well supplied with phosphate and lime, is one of the best crops to grow for green manuring in many parts of Australia. The use of this plant for this purpose has not been advocated so far as the writer is aware, and of course its value yet remains to be proved. He makes the suggestion because, of all the annual clovers and trefoils, it seems to come first, make the best growth in winter and early spring, is very hardy, and gives a good supply of green stuff for ploughing in.

How plant food is held in the soil. The farmer uses superphosphate, in which the phosphoric acid is in the water-soluble form, nitrate of soda, sulphate of ammonia, the liquid manures from the stable are also soluble in water, and so also are the potash manures commonly used. It is important that we try to understand what becomes of these substances when they are applied to the soil, and rain follows sufficiently heavy to percolate through the soil. Are the fertilising substances washed away, if not used at once, or do they remain in the soil for the future use of plants when required? This is a practical matter to the agriculturist.

Elaborate experiments have been carried on by various investigators at Rothamsted and elsewhere. Daily analyses have been made of the drainage water from heavily fertilised fields in fallow and carrying crops, and the evidence seems conclusive that **all well constituted soils have the power of quickly taking up the plant foods from the fertilisers, and of holding most of them until required for the use of plants.** The exceptions are ammonia compounds and nitrates. In the case of phosphoric acid, no leaching takes place in well constituted soils, and practically the same may be said of the potash. Investigations at Rothamsted showed that the phosphoric acid was not even washed into the subsoil, but in the case of the potash the percentage in the subsoil was increased. It is recognised that the percentage of carbonate of lime, clay and humus in the soil plays an important part in this connection. This point must be remembered in relation to the treatment of very sandy leachy soils.

Practical bearing on phosphatic fertilisers. These facts have a practical bearing on the application of phosphatic and potash fertilisers. With ordinary soils there is no danger of losing soluble phosphates, or even of their being washed deep down into the soil. The exceptions are sand and powdered silicates like feldspar, for, according to Hall, these have been found to possess little or no power of removing phosphoric acid from solution. Carbonate of lime possesses the greatest power of fixing soluble phosphates, and next to this, red and yellow clays; but the compounds formed with clay are less available for the use of plants. Therefore, if superphosphate is applied liberally to soils deficient in phosphoric acid, as most Australian soils appear to be, in order to build up a reserve of this important plant food, it is important that there be a sufficient supply of carbonate of lime in the soil with which the phosphoric acid may combine.

Bearing on potash manures. To a considerable extent what has been said of phosphates applies to potash manures. These also may be safely applied to the soil, without danger of loss, well in advance of the actual needs of the crop, in order to be well distributed through the soil.

Retention of nitrogen. The retention of nitrogen compounds in the soil is a different problem, because they are so intimately associated with bacterial life in the soil. When soluble organic nitrogen compounds, such as urea and ammonia salts, enter the soil in solution, they are removed from solution by well constituted soil, but nitrates are only slightly retained when there is a flow of water through the soil. These facts are illustrated practically in the case of sewage farms, and in the deodorising effect of earth closets. In the retention of ammonia salts the presence of carbonate of lime, clay and humus play an important part. When organic nitrogen compounds are changed to nitrates, they are liable, unless at once used, to be washed away in drainage water.

Bearing these facts in mind, nitrates should only be applied to the land when the plants are growing and ready to use them, and they should only be applied in quantities which can be used. To a lesser degree the same remark applies to sulphate of ammonia and such quickly changing organic nitrogenous fertilisers as urea and blood manure.

THE USE OF LIME IN AGRICULTURE.

Necessity for lime. The practice of applying lime to agricultural land is a very old one, but as with many other customs the reason why it exercises so good an effect has only comparatively recently been explained. In Australia, liming the land is uncommon, and there is very little regular trade in ground limestone or in ground quicklime. A considerable amount of advertising has been done in advocating the use of gypsum, especially in Victoria and South Australia, but gypsum is not lime. Its action is in many respects different, and it must not be confused with lime. There is a little trade in each State in quicklime and the waste from the lime kilns for use on the land, but liming the land is not a recognised custom in connection with Australian agriculture, and its importance in connection with soil fertility is hardly thought of. This is greatly to be regretted.

Hall says: "Of all methods of improving the soil, other than actual manuring and cultivation, none is more important than the incorporation of lime." Many of our soils are rich in lime, but there is ample evidence to show that Australian agriculturists should devote much greater attention to this matter than has been the custom. In some districts with regular and ample rainfall, where mixed farming is carried on, the use of carbonate of lime will often produce as wonderful an influence as the application of superphosphate has done in wheat growing; and where superphosphate is used, the use of lime is a necessity if there is not already sufficient in the soil.

Strictly speaking, lime should mean calcium oxide or quicklime, such as is used by builders, but the term is commonly used in a much wider sense.

Limestone. Limestone, or carbonate of lime, is calcium carbonate or a combination of calcium and carbonic acid. Carbonate of lime may be in the form of rock, and vary much in appearance and texture. Marble is almost pure carbonate of lime. Limestone may have a sandstone-like appearance and vary much in purity. It may be in deposits left by evaporation of water charged with lime, as in the cave stalactites and in the deposits of limestone crusts or travertine limestone, so common over large areas in many places in the various States. This kind may vary from a hard rock to soft, white, powdery material, varying greatly in purity through the admixture of clay and sand. Any of these forms is readily acted on by acid, which will cause effervescing, the gas given off being carbonic acid gas, the same as in soda water, for producing which the pure crystalline forms are often used.

Quicklime. Quicklime, burnt lime, caustic lime, or calcium oxide, are names meaning the same thing, and in English and American books several other terms, such as cob lime, shell lime, lump lime are applied to it. When carbonate of lime in any of the forms mentioned in the previous paragraph is heated strongly in a kiln the carbonic acid is given off and lime oxide is left. In burning marble or other forms of fairly pure carbonate of lime, about 44 per cent. of the weight is lost in the form of gas; or, in other words, if a limestone be very pure, one ton will produce about 11¼ cwt. of quicklime. Caustic lime has a special value for application to heavy clay soils.

Slaked lime. Slaked lime is the combination of quicklime with water. Everyone knows the properties of quicklime, how greedy it is for water, and how it swells, becomes boiling hot, and, if too much water is not used, crumbles into a fine dry powder. This powder is slaked lime, or calcium hydrate, and will, if the lime be pure, consist of about 76 per cent. of calcium oxide and 24 per cent. of water. A ton of quicklime will therefore make 26⅓ cwt. of slaked lime, or in other words, one ton of pure limestone gives about 11¼ cwt. quicklime, and this produces with water about 14¾ cwt. of slaked lime. The expansion caused by wetting quicklime in a barrel, bag, or box is sufficient to burst anything but an immensely strong vessel, and the heat will cause fire. As the air always contains water-vapour, the only way to keep quicklime is in closely-fitted air-tight drums or tins.

Air-slaked lime. It is well known how quicklime, left exposed to the air, crumbles into powder. It is also known that bags of quicklime begin to swell when exposed to the air, and then burst. In a very moist atmosphere the production of slaked lime is very rapid, and in this case the product is practically slaked lime as above described, but in ordinary air-slaked lime this is not so, for the change is a double one. Not only does the lime absorb moisture, but it also takes up carbonic acid from the air, and forms a mixture of slaked lime and carbonate of lime. The longer it is exposed to the air the more carbonic acid it absorbs, so that after lying in the air for sufficient time it is simply powdery carbonate, having lost all its caustic qualities. This is precisely what takes place in the soil. Quicklime and slaked lime are not found in nature. They are prepared from carbonate of lime and revert back to it. Their use in agriculture is chiefly a matter of convenience. Carbonate of lime is what the soil specially requires.

Calcium sulphate, or gypsum. Gypsum, or calcium sulphate, is quite a different mineral from calcium carbonate or common limestone. It is not lime. In the carbonate we have seen that the oxide of the metal calcium is the base combined with carbonic acid. In gypsum the same base is combined with sulphuric acid. When we heat the carbonate we get quicklime, but when we do the same with gypsum, we drive off water and get Plaster of Paris.

A great deal of confusion exists about the value of gypsum to the farmer. It is valuable in certain cases, but, as may be seen from its composition, it cannot be used as a substitute for lime. Its action is different. It will serve as a supply of calcium as plant food and it acts chemically on various substances in the soil, in some cases setting free potash, and making it available for plant food. In America, gypsum is known as land plaster. It is used considerably in some places for clover lands, but the point we wish to strongly emphasise is that when farmers are advised to lime the land, gypsum is not the substance referred to. It is not and cannot take the place of carbonate of lime. One point more may be mentioned, and that is, when gypsum is used, it should be applied in the form of a fine powder, *i.e.* flour gypsum, and not sand or crystal gypsum. The finer the material the greater its value, provided the composition is good. Natural flour gypsum or ground gypsum should be used, not burned gypsum.

Why lime is applied to the land. The next step is to consider the objects sought in applying lime to the soil. As in most other matters of practical agriculture, modern science has only explained the reason for doing things which agriculturalists have done for unknown centuries. Sometimes the understanding of the reason suggests the accomplishment of the object by more simple means, and this is the case with lime, but even then it is practical experiment alone which determines the matter. The application of marl, shell sand, chalk, limestone, quicklime, etc., has been practised in almost every country where agriculture has progressed from the most remote periods of history. Theories have from time to time been advanced to explain the reason for the benefits known to be derived, and many of these have been shown to be absurd, but the simple fact remains, that the application of carbonate of lime in one form or another produces beneficial results under various conditions, and modern science has explained why.

It is now generally recognised that the action of lime in producing better crops is indirect. Calcium is a necessary constituent of plants, but it is very seldom that there is not enough in the soil in one form or another for this purpose.

Physical and chemical action. 1. Lime may serve a useful and valuable purpose in altering the physical character of soil. This is explained elsewhere.

2. It acts chemically in setting free other plant food, such as potash, etc. It may even, according to Hall, act in some cases as a liberator of phosphoric acid from phosphates of iron and alumina.

3. It is necessary as a base to satisfy the requirements of such fertilisers as sulphate of ammonia and superphosphate. The retention of ammonium salts is dependent on the presence of both calcium carbonate and of clay and humus in the soil. In this connection A. D. Hall says: "Only carbonate of lime, or quicklime and slaked lime, which promptly become carbonate of lime when incorporated with the soil, are capable of acting as the required base."

4. Carbonate of lime corrects the acidity of soils, and the result of this chemical action is to make the soil a more congenial home for the micro-organisms which act on organic matter, changing the complex nitrogen compounds into nitrates, and at the same time it affords the necessary base for the formation of the new compounds which are available as plant food. This is one of its most important functions.

Lime and micro-organisms. The processes of decay of organic matter in soil are really slow methods of combustion or oxidation. These processes give rise to the formation of acids, and all know that it is a common thing to speak of swamp soils rich in vegetable matter as sour.

But a soil need not be swampy to give an acid reaction, and, as a matter of fact, whenever there is a considerable amount of organic matter or humus in a wet soil, acids are formed, and the presence of an available, easily attacked base, is necessary for their fixation as a preliminary to the oxidation work of the soil bacteria. The process is complex because the work itself is done by the micro-organisms, and when these by their work have created an acid condition, the soil is no longer congenial to their existence. Carbonate of lime affords the necessary base, and leads to the more rapid decay of organic matter and the consequent release of plant food.

Mr. A. D. Hall says, referring of course to English conditions, which in this case we think will apply here : " The use of artificial manures generally demands an increased rather than a lessened attention to the periodical liming of the land." If, however, the farmer or gardener uses lime to hasten the process of oxidisation of the humus of his soil, he must not neglect to keep up the supply. This can be done by the use of stable manure or the ploughing in of some kind of vegetable matter, whether it be weeds, stubble, green crops, or pasture. The increased supply of roots, resulting from the big crops grown on limed land, helps to keep up the supply of humus.

Applying lime. We are now in a position to discuss the application of lime. It will be seen that carbonate of lime is the natural article, but, as a rule, it is in the form of rock which cannot be economically applied to the land. To be useful the lime must be in the form of a powder, the finer the better. Marl can be applied as dug, and is good where available. Beds of soft carbonate are often fairly pure, and can be readily reduced to a fine powder, and are therefore valuable to the farmer. It cannot be too clearly understood that the value of a lime material to the agriculturist depends on its richness in carbonate of lime, and agricultural lime should be sold on analysis the same as fertilisers.

Ground carbonate of lime. It is amply proved by experiments carried out by the Agriculture Department of the Lancaster County Council, and recorded in the *Journal of the Board of Agriculture*, January, 1907, that ground carbonate of lime is "easier to handle, and involves less labour than does ordinary quicklime," and as "compared with ground quicklime it has not the same irritating effect on the eyes and nose, and drops more readily from a slag sower (drill) in breezy weather. "The results indicate (cost, carriage, and other factors are duly considered) that ground limestone is a more profitable dressing" than either ground quicklime or lump lime. American experience has proved the value of ground carbonate even more widely and conclusively; and it has been tested with success in New Zealand. It is suitable for every purpose, except the liming of heavy clay lands, to modify the physical condition; but there is one drawback to its use when it has to be carted long distances. Allowing for impurities, about 12 cwt. of quicklime are as good as one ton of ground limestone.

Ground quicklime. The report above referred to says: "Ground lime should not be delivered at the farm until all arrangements have been made for its application, as loss will be occasioned by the bursting of the bags. The ground lime should be finely ground, so that not less than 35 per cent. will pass through a sieve with 10,000 holes to the square inch, and should contain 90 per cent. of lime (calcium oxide)." This high percentage is only possible when the lime is made from very pure material such as marble or crystalline limestone. This shows the necessity for having lime sold on analysis the same as fertilisers, a wider margin of error being allowed.

Our present conditions. At present neither finely ground carbonate nor ground quicklime is as a rule available to the farmer, so that the practical consideration at the present time is, which of the available forms of lime is it best to use? The best plan at present seems to be to get good fresh burnt lime and cart it to the field in that condition, then shake it carefully to secure as fine a dry powder as possible, and apply to the land with a fertiliser distributor, or failing that, a drill with the hoes off. If limestone be available near at hand the farmer can burn it himself, cart the burnt lime into the field and dump it in heaps like stable manure. Cover these with a little soil, and when the lime is slaked carefully spread it with a shovel the same as stable manure. It is well to spread it as soon as it falls to a fine powder. Any convenient time will do for the application. It may be put on the fallow land and cultivated in, and that is probably as good a plan as any. In sour land a good method is to spread a dressing on the land before the ploughing, and give another with the fertiliser distributor afterwards. It is worth remembering that the best effects may not be seen for a season.

Quantity to apply. The quantity per acre depends on the character of the soil, the purpose for which it is being applied, and the cost. A dressing of 5 cwt. of quicklime, which is equal to a little more than 6½ of slaked lime, or nearly 9 cwt. of carbonate of lime, may be put down at a minimum, while four times this quantity of mild lime may be wise. Some care as to quantity and time of application should be exercised with quicklime; but with carbonate the only consideration is one of expense. Carbonate of lime is neutral and can do no harm. Fifty tons to the acre of ground carbonate would be under three per cent. in the top foot of soil, and many rich calcareous soils contain much more than that. Work according to the soil and other practical considerations. If the soil needs lime, the farmer will find that it will pay to give as much as he can afford up to one per cent. in the top nine inches. For lucerne on land poor in lime even five or ten tons of carbonate of lime per acre may prove profitable. Wing states very emphatically that in America lack of lime is responsible for more failures of lucerne than any other single factor.

Liming involves manuring. There is a very old couplet running:

> "Lime and lime without manure
> Will make both land and farmer poor."

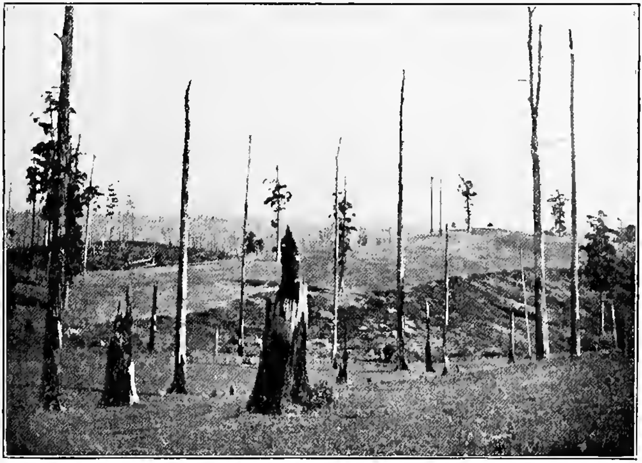
In another form the saying reads: "Lime enriches the father and impoverishes the son." As with many old sayings, while conveying a good idea, the statements are entirely misleading in the light of modern knowledge. It is rare indeed that there is not sufficient of the element calcium in the soil in some form to supply what the plant needs for its development. The application of lime improves the physical condition of the soil, and renders the plant food in the soil available alike by its direct chemical action and its promotion of bacterial life. Its use is a part of good farming under many conditions, and is an important factor in building up a fertile soil, which will enrich the farmer and his son and his son's sons for many generations. Joseph E. Wing modernises the old saw and says: "Lime enriches the father and the want of it impoverishes the son."

The soil of a farm which has long been under intense cultivation with heavy manuring may contain big reserves of accumulated plant food, which are of no use because unavailable. What is the use of it either to the father or to his son? The use of lime makes these reserves available, pays its own cost, sweetens and ameliorates the soil, gives the micro-organic life new vigour and favourable conditions, and provides the farmer with cash to further enrich the land. Of course it leads to the more rapid oxidation of humus, but it produces bigger crops of grass and fodder, especially clovers and lucerne, to replace it by the decay of roots and through the stock of the farm. It has a marked effect in rendering the reserves of potash available, but it provides cash to pay for more. It is necessary as a base to enable the soil in humid districts to retain and use artificial fertilisers, and it often exercises a most beneficial effect in preventing the destructive effects of some soil fungi, such as " funger-and-toe " in cabbages, turnips, rape and so forth. From many years' observation the writer is convinced that no single practice is more needed on many of the old farms and gardens in the older settled districts of good rainfall in all the States than the free use of lime, finely powdered carbonate or ground limestone being the preferable form if procurable. It is to be hoped that before many years are passed facilities will have been provided for enabling farmers to obtain cheap supplies of this important soil ameliorator.

PASTURES.

PROBABLY no section of this book is more difficult to deal with than the subject of pastures. Australia is the biggest producer of sheep and wool in the world, and her herds of cattle and horses are by no means insignificant even as compared with those of other countries. The vast majority of the flocks and herds are raised on the natural pastures, which owe nothing to man, unless it be overstocking and bad treatment. The treatment of purely pastoral country is beyond the scope of a text-book on the principles of general agriculture, but when we remember that we are feeding over ninety-two million sheep, over eleven million cattle and over two million horses on natural pasture, we see the absurdity of such statements as Australia has few permanent pastures.

Indigenous and introduced pasture plants. In the early days of settlement, the natural pasture grasses and other fodder plants were wonderfully luxuriant over wide areas of the more open country in the regions of more regular and heavier rainfall. The general effect on the soil from two generations of settlement is referred to elsewhere. In the pasture itself, the result in many cases has been to eat out or destroy many of the more valuable perennial fodder plants. In some cases their place has been taken by more hardy, harsher and less valuable species of indigenous vegetation, like "spear" and "corkscrew" grasses, while in others introduced plants have more or less completely taken possession of whole districts. A few of these are probably as valuable as those they have supplanted; but as a rule this is not so. So greatly has the character of the vegetation changed, and so general and widespread are some of these exotics, that the majority of people look upon



Eradicating Bracken Fern in South Gippsland.

The hillside shows natural bracken. The top of the hill was the same the year before. It was disc ploughed in early Summer and harrowed well. The treatment was repeated at the end of Summer and grass and clover was sown.

them as native plants. Among three hundred and sixty-four given in Ewart's *Weeds, Poison Plants, Naturalized Aliens*, the following will illustrate the point. The burr clover (*Medicago denticulata*) and a number of other common widely spread clovers and trefoils, of greater or less value according to circumstances, are natives of Europe. The common sorrel (*Rheum acetosella, L.*), wire weed or hog weed (*Polygonum aviculare, L.*) is an introduction, as is also the Cape weed (*Cryptostemma calendulacium, R. B.*); sow thistles (*Sonchus oleraceus, L.*), cockspur (*Centaurea melitensis, L.*), barley grass (*Hordeum murinum, L.*), all have come to us from Europe. The common couch grass (*Cynodon dactylon, Pers.*) is the doub grass of India, and is called Bermuda grass in America; and so we might go on for pages.

Effect of cultivation. When the land has been at some time broken up and brought under cultivation, the indigenous vegetation has to a very large extent disappeared altogether. This is to be regretted, because many of the grasses, etc., possessed high feeding value and were entirely suited to our climatic conditions. It would appear highly desirable that systematic work should be undertaken, by either the Federal or State Governments, to select the best of these nearly extinct plants and adapt them to conditions of cultivation. We go to vast trouble and expense in introducing fodder plants from other parts of the world and entirely neglect our own. This does not appear to be sound policy. All that the individual farmer can do with any natural pasture he has is to exercise care in stocking, allow the few survivors to mature and seed, and in many cases apply fertiliser to the land.

With the cultivated land the problem is entirely different. In the wheat areas the only practical rotation at present is first, wheat, second, pasture, third, fallow, and then wheat again. In the regions of better rainfall the system may be extended. This question of rotations in our districts of better rainfall has not yet been worked out. Rape, peas, oats and crimson clover should certainly have regular places in many districts. The work being done by Professor Perkins at Roseworthy Agricultural College is the best of its kind in Australia, and will in due time practically settle the question for districts having similar climatic and soil conditions, and might well be taken as a model for similar work elsewhere.

The meaning of the word grass. At this point it is desirable that we should explain the difference between the meaning of the word grass, as used by the farmer and as defined by the botanist.

Botanically, a grass is an endogenous plant, the seedling of which has a single leaf and the adult plant simple leaves, a stem generally jointed and tubular, the husks or glumes in pairs, and the seeds single. Botanically, the bamboo, maize, sorghums, millets, sugar cane, wheat, oats, barley, rye, and rice are as much grasses as cocksfoot, ryegrass, paspalum, couch or prairie grass ; while clovers, trefoils, lucerne, peas, beans, melilot, vetches, sheep's burnet, saltbush, geranium, Cape weed, thistles, and a multitude of other good fodder plants are not.

On the other hand, as commonly used the word grass excludes a great many of the botanical grasses like the bamboo, wheat, maize, barley, etc., and includes any herbage or small plant, not large enough to be called a shrub, which forms pasturage for stock.

It is well to remember this difference, but it is useless in everyday life to attempt to keep the two terms distinct. As a matter of fact, the popular use of the word is centuries older than the botanical classification, and has its origin in an old English word meaning to graze. The use of the terms pasture plants and pasture gets over the difficulty to a large extent, but the use of such expressions as grass land, grass seeds, fed on grass, are too general to be changed.

Climate and nutritive value of pasture. The character of a pasture chiefly depends on climate, although the soil conditions often determine what particular pasture plants will thrive. This is so true that it is easy to judge by the nature of the pasture what must be the general character of the climate. Further than this, if we know the climate we can very often judge the nature of the soil by the character of the vegetation. Another point to be remembered is that the nutritive value of a pasture cannot be judged by its freshness, greenness and luxuriance. Very often has the writer heard stockmen say in varying terms, " Oh, yes, the Mount Gambier grass is green enough, but give me the grass of the north to fatten stock," or " Gippsland grass may be green and luxuriant but it has not the fattening qualities of the Riverina feed." Similar comparisons might be made in New

South Wales and Queensland, but these will illustrate the point.

Climatic conditions and pasture. One of the characteristics of much of the Australian agricultural country is the more or less dry summer. The seasons are not clearly defined. In Tasmania and Southern Victoria the rainfall is fairly evenly distributed through every month of the year. Queensland, the Northern Territory and the North-West of Western Australia have their rainy season in summer, and the coastal and northern districts of New South Wales generally have summer rains; but speaking generally with regard to the agricultural districts in the more temperate parts of the southern half of Australia the year may be divided into

A Pastoralist's Dam.

two periods of seven rainy months, from April to October, and five dry months, from November to March. In the agricultural areas of Western Australia this is so strictly true that about 90 per cent. of the average rain falls in the seven months. At Adelaide, about 75 per cent. of the average of 21 inches falls during the same period, and in the dryer more uncertain northern areas and in Northern Victoria about 66 per cent. The summer fall is in the form of uncertain thunderstorms and cannot be relied upon. Under such conditions we have a rapid autumn growth, if the rains come early; and, always in normal years, a luxuriant spring growth and only dry feed in summer. This dry feed is, however, more like natural hay, and on it the stock maintain condition and thrive.

Permanent pastures. In Britain a permanent pasture is land laid down to mixed fodder plants and kept for grazing for many years. It is comparatively unproductive during the cold winter season, but is permanently green during the spring, summer, and autumn. Such pastures are only possible in the cool south-east part of Australia, where there is a good regular summer rainfall. In Tasmania the conditions are more favourable for pastures on the English plan, and in New Zealand they are a prominent feature of farming. In the extra-tropical portions of Eastern Australia, where the rains fall chiefly in summer, the conditions are entirely favourable for such grasses as paspalum and Rhodes grass, as well as lucerne, and these plants have revolutionised the pasture conditions of the coastal district of New South Wales and

Southern Queensland. It may be repeated that the pasture problem is largely a question of rainfall, distribution being as important as amount. For this reason hundreds of tons of English grass seeds, used from time to time, have not returned their cost to the purchasers. Every year, however, a fresh lot of enthusiasts try again, only to find that grasses which thrive in a climate where a fortnight of rainless weather is a novelty are not suited for a climate with five hot months which may be practically rainless, or only subject to occasional thunder storms.

A Sheep Farmer's Home.

In the English sense, there are not, and cannot be, permanent pastures over the greater portion of the Commonwealth, and yet Australia is the greatest sheep, and one of the best dairying, countries in the world. Leaving out the purely pastoral country, and considering only the portions where the rainfall is sufficient in amount and regular enough in distribution to render farming profitable, we have to consider the character of the fodder plants on which the farmer feeds his stock. The problem is solved by the natural law of equalisation. Where pastures are permanently green in summer they are not of much use in winter. Where they are dry in summer they make proportionally greater growth during the rainy season.

Dairy Country, South Gippsland.

The timber is rung, scrub cut and burned and grass sown.

Under the climatic conditions of, say, seven rainy and five dry months, perennial grasses become dormant in summer. They are almost invariably tussocky in character, and seldom or never make a close sward. They are, as a rule, very nutritious, and even when dry support stock very well, because under summer conditions in Australia an animal requires but little food to maintain the warmth of the body. Under these conditions, the most profitable seeds to sow are annuals, and very much can be done in supplanting the common poor silver grass, barley grass, sterile brome grass, etc., by more nutritious plants, such as the creeping clovers and trefoils, which, with phosphates, will crowd out the more worthless things. Two cultivated annual pasture plants, which seem to have not received the attention they deserve, are crimson clover and Italian rye.

Effect of grazing on soil fertility. The question of the effect of grazing stock on pasture land has been referred to in the chapter on soils; but it must be considered more in detail here, because it may be looked at from several points of view, and is of very great importance. These may be clearly put in the form of questions.

(1) Do stock grazing on pasture land remove soil fertility?

(2) Which will improve the fertility of a paddock the more, leaving it absolutely idle for, say, five or ten years, or keeping it fed down by stock for the same length of time?

(3) Does leaving a field in pasture, which is fed down by stock, improve the fertility?

At first reading, these questions may appear to be the same, but such is not the case.

The answer to the first question is—Stock grazing on pasture remove from the soil an amount of fertility corresponding to the quantity of wool, butter, and meat produced from eating the herbage.

In reply to the second question, it may be said with equal definiteness that the fertility of a paddock left absolutely alone, so that all the herbage which grows is allowed to decay and go back to the soil, will improve much more than one kept down by stock.

A Northern Tasmanian Farm near Devonport.

The answer to the third question is that, laying down a field to pasture, or even allowing it to grow any self-sown herbage, and grazing it for a number of years, is an old and proved method of improving fertility.

We will now briefly discuss the three questions together. We have seen that soils are practically inexhaustible, that fertility, provided climatic conditions are favourable, is only a question of degree, that plant food exists in the soil in two forms known as available plant food, and reserve materials which slowly become available, that if soil is kept under crop, or even under grass continually, the annual growth under favourable climatic conditions, in proportion to the amount of available plant food, and that the growth is determined by the form of plant food which is least plentiful.

If the annual crop of vegetation of any kind is returned each year back to the land, the soil becomes annually richer. If we remove the annual crop either by harvesting or grazing, and that crop takes from the soil more plant food than becomes available during the year, we decrease the available plant food by that amount. We may go on doing this until a stage is reached when the annual crop of vegetation exactly balances the yearly available supply of the least plentiful plant food; but during these years there may be a considerable increase in the other plant foods, and then a dressing with a special fertiliser supplying the one which is deficient has a wonderful effect. This was the case all over Australia when the use of phosphatic fertilisers became general in the nineties. Land which was so exhausted that it refused to grow profitable crops gave a fourfold return. Land which had been under grass for years producing only a scanty pasture, when top dressed with phosphate responded in a marvellous manner by keeping from two to four times the number of stock.

When stock graze on pasture they return the larger portion of the food they consume in the solid and liquid droppings, the amount of plant food they take away in the form of wool, milk and flesh being seldom equal to the annual reserve made available by natural agencies. At the same time the effect of top dressing with phosphates is generally so pronounced that we can only conclude that most of the pasture lands of Australia, within the region of good regular rainfall, have, to a very considerable extent, had their supply of phosphoric acid reduced, and the general use of phosphatic fertilisers would prove as profitable as on wheat lands.

Effect of phosphates on pastures. Having made it quite clear that grazing of stock on pasture land does remove plant food, and may so reduce the available supply of the least abundant, and therefore the one which controls the growth, we are in a position to consider the question of applying fertilisers to pasture land. We must look at the matter from the practical economical point of view of profit.

From the experience or evidence available we may limit our discussion to phosphates, with the use of which we must also consider the importance of lime. As a rule, at present the use of lime may be postponed, especially if Thomas phosphate is the form of phosphate used. The farmer must, however, remember what has been said about the use of lime elsewhere.

First: If superphosphate be applied to land deficient in lime, liming is a necessary part of the business.

Second: Lime itself may have such a marked effect on pastures that it is often profitable to use it alone, because it sweetens the soil, renders potash, nitrogen, and other plant food available, and often quite changes the character of the herbage. On tens of thousands of acres of land, in the wetter districts of Australia, the use of lime would pay a profit on the application, even at present high prices.

The effect of phosphates on pasture is seen in two ways. First, where it is needed, it will often entirely change the character of vegetation without any seed being sown. This is a matter of common knowledge in Europe and America as well as in Australia. Many examples could be given from available literature, particularly from the Rothamsted experiments; but they would not convince the farmer who has the means of proof in his own hands. This is a severely practical matter, and all he has to do is to apply a dressing of phosphate across a pasture field and watch the result.

1. If the stock are running on it, he will almost invariably find that they love that strip better than the balance of the paddock.

2. If he shuts up the paddock, or fences off a portion of treated and untreated he will find, if phosphates are required, that the fertilised portion makes a marvellously more rapid and luxuriant growth.

3. If he examines the plants carefully, especially the second year, he will find that the poor grasses

are being crowded out by luxuriant wild clovers, trefoils, and the more valuable varieties of grass.

From time to time results of top dressing pasture have been published in the Agricultural press of all the States, and there is no manner of doubt about what we are saying; but one illustration from our own experience will perhaps fix attention better than a mass of details. In order that the reader may see that fertilising pastures should not be confined to poor land, where it certainly gives wonderful results, the analysis is given of the soil of the field under notice.

The field in question is on the Ferndale estate, Balingup, Western Australia, but the results were not more pronounced than on other farms in other States. The soil is a dark alluvial, which has not been ploughed for at least ten years, and is covered with a dense sward of couch grass which is dormant in winter, during which season the paddock carries a good growth of wild clovers, trefoils, etc., and without fertiliser was considered one of the best paddocks in the district.

The following are the chemical and mechanical analysis before the application of about two cwt. of Thomas phosphate to the acre, applied with a Jack's fertiliser distributor at a cost of about 10s. an acre. The result is from an average of six samples taken by the writer, the analysis being made by the Government analyst. Apart from its relation to the present question, it will serve as an illustration of what a soil analysis teaches:

Report of Analysis of Soil.

Nature of soil,	Sandy.
Colour of soil,	Black.
Reaction of soil,	Slightly acid.
Apparent specific gravity,	1·14.
Absolute weight per acre (9 ins. deep),	2,324,460 lbs.

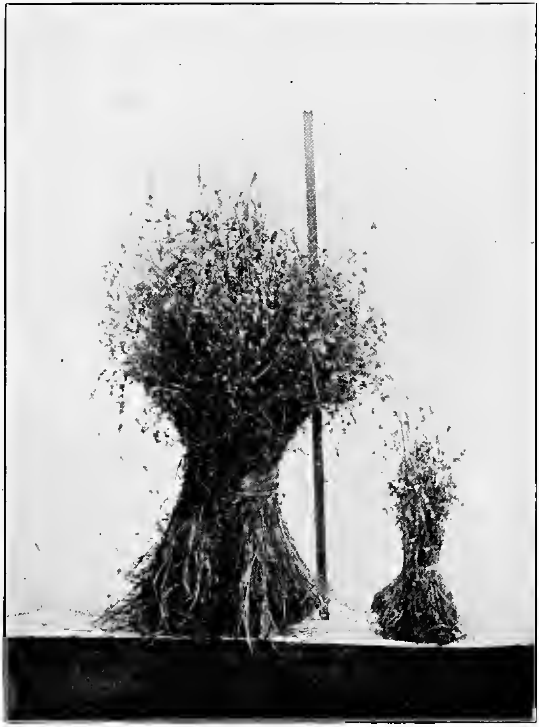
Mechanical Analysis.

Coarse gravel, more than 1 millimetre diameter,	·90.
Fine gravel, more than 1 millimetre diameter, -	1·96.
Coarse sand, ·1 to ·5 millimetre,	5·38.
Medium sand, ·5 to ·1 millimetre,	35·15.
Fine sand, ·1 to ·05 millimetre,	8·53.
Silt, ·05 to ·02 millimetre,	7·64.
Fine silt, ·02 to ·01 millimetre,	4·28.
Clay, less than ·01 millimetre, -	36·16.

Proportion of Fertilising Substances.

	Total (soluble in strong hydrochloric acid).		Available soluble in 1 per cent. citric acid.	
	Per cent.	Quan. in 1 acre of soil (9 in. deep).	Per cent.	Quan. in 1 acre (9 in. deep).
Nitrogen,	·28	6150 lbs.		
Lime (CaO),	·49	11,387 ,,		
Potash (K_2O),	·214	4973 ,,	·012	279 lbs.
Phosphoric acid (P_2O_5),	·048	1215 ,,	·005	116 ,,
Chlorine,	·012	460 ,, salt.		

Result of an application of phosphate. The fertiliser was applied in March, 1907, and the field was grazed as usual with horses, cattle and sheep. When inspected in July there was no difficulty in noting any parts which had been missed, partly by the way the stock persistently fed on the fertilised land. As the season advanced and the pasture got away from the stock the difference became more noticeable. About the middle of October the paddock was shut up until December, when it was cut for clover hay.



Naturally Sown Clovers from the same Area of Ground.
The effect of phosphates on pasture. Ferndale, Balingup, Western Australia.

An inspection was made and photographs were taken during the first week in December. The unfertilised portion, after the rest, was patchy and uneven. Where the soil had been enriched by cow and horse droppings the growth was rank, and was chiefly clover. Between these tufts, it was thick but short and poorly developed with a good deal of silver grass. Where fertilised, the land carried a dense even crop of clover. We carefully measured a rod of average fertilised and unfertilised land, cut the crop, and next day weighed the produce. The product of the unfertilised ground worked out at 1.77 tons of wilted stuff to the acre, while the fertilised plot gave 8.2 tons, and these figures may be taken as the average difference.

Taking a small patch of average fertilised and unfertilised, away from droppings, we cut the plants from the one and pulled them up from the other, tied them in bundles and photographed them side by side. The comparison fairly shows the effect of the dressing of phosphate. The results were not as good the second year, and were still less the third; but the effect is still pronounced in the fourth season.

A careful examination of the clovers showed that Trifolium minus predominated, the balance being made up of yellow hop clover (*Trifolium procumbens*), clustered clover (*Trifolium glomeratum*), and burr trefoil (*Medicago denticulata*).

In estimating the value of the dressing of phosphate, we must not only consider the increase of, say, four times the yield of hay after the paddock had been shut up seven weeks, but also the value of the pasture for the rest of the year and subsequent years, for during the summer the effect on the couch grass is very pronounced.

How to apply phosphate to pasture. For top dressing pastures where the rainfall is under, say, twenty to twenty-five inches, the use of superphosphate is recommended where the rainfall is heavy, Thomas phosphate is generally the cheaper and better form. For distribution, if the weather is perfectly calm, a broadcast seed sower, on a cart, answers well, and by this means light dressings can easily be applied, and the effect will be seen where the dust blows. Where small areas only have to be dealt with, an ordinary drill, with the tubes off, answers fairly well, but the distribution is not perfect. The best plan we know of is to use a Wallace, Jack's, or similar fertiliser distributor. These machines are in

Clover and Trefoil Hay on Couch Grassland not Cultivated for Eight Years.

The result of the application of phosphates: yield over 30 cwt. to the acre.

general use in Britain, and they are becoming fairly common in Western Australia. The quantity to apply will depend on conditions and the money which the farmer can spare for the purpose. It may range from 56 lbs. to two cwt. per acre. Where the rainfall is good not less than one cwt. should be used. The application may be made at any time before or soon after rainy season starts. One of the effects is to force early feed, and the reason for an early application is evident. The effect of one dressing will be seen for a number of years.

FOOD AND ITS FUNCTIONS.

Australian conditions. Apart from working horses, dairy cattle, pigs, poultry, and, to a very small extent, stud sheep, hand feeding of stock is not practised in Australia. In spite of the wonder expressed by the new arrival in summer, our stock thrive on what they can gather. The price of labour exercises considerable influence on our practice, but the controlling factor is the climate, which is so mild that housing of stock is not necessary. There is room for vast improvement in many directions, especially in connection with dairy cattle, which might be made to double the present average product by systematic testing, culling and feeding.

Our feeding practice differs from that of Britain and America in another important way. Our range of available food stuffs is much more limited, so that the rations of standard books help us but little. Our methods are rough and ready, but the supreme test is the condition of the animal fed ; together with, in the case of the horse, his capacity for work, and in the cow the product of milk ; and, judged by this standard, our methods are not as far wrong as some would have us believe, although it is probable they are often wasteful.

The function of food. The food taken by an animal serves several purposes in connection with the functions of the body:

1. The young animal has to grow, and material is required to form the tissues and organs of the body.

2. Food is necessary to provide fuel to maintain the heat of the body, without which the vital processes cannot go on.

3. The animal uses energy, and food is required to repair the waste of the various tissues, organs, etc., of the body.

4. The female requires extra food when she is to produce young.

5. If the animal is performing muscular labour, if it be producing milk, growing wool, or laying on a reserve of fat, food is required in proportion to the effort. The digestion of food requires energy, and if the food is indigestible energy is wasted. The value in fodder is the difference between the available energy in the fodder and that required by the animal to extract it. In other words, a cow will give more milk, a horse will do more work, and a beast will lay on more fat when fed on digestible suitable food than otherwise. Some substances require so much energy on the part of the animal to even partially digest them that they are quite unsuitable for fodder. It is only after the needs of the animal to maintain heat, to grow, and to exert the necessary energy for digestion, movement, work, etc., are satisfied that it will begin to lay up a reserve in the form of fat.

Only part of the food consumed by an animal is digested; and it is only that which is digested that is of use. That which is not used passes out through the intestines as solid excrement. Good easily digested food is necessary for animals required to produce commercial products, such as milk, wool, or eggs; or to perform work, as with the horse; or to lay on condition ready for market as fat stock.

The proportion of food digested varies with the character of the food and the individual disposition of the animal. One animal may digest 80 per cent. of a given food, while another will not utilise much more than half the proportion. The farmer desires a good doer, or an animal that will use as much as possible of the food it consumes. As a general rule, animals digest from one-half to two-thirds of what they consume.

Composition of fodders. In the study of the plant we found that, as a rule, it consists of about thirteen elementary substances, but they are combined into a vast variety of compounds. These may, however, be readily classified into five important groups: 1, water; 2, ash; 3, carbohydrates, including fibre; 4, fat; and 5, albuminoids, or proteins.

In the chapter on how plants grow, we referred briefly to these groups. It was there seen that some plants used for food, such as cabbages, turnips, rape, etc., may contain over 90 per cent. of water, whereas air-dry fodder like grain and hay may contain 10 to 15 per cent. Watery fodder reduces the amount of water which the animal using it requires to drink; but no food is so watery that it will supply the domestic animals with all the water they require.

Water renders food more tender, juicy, and generally more palatable. Thus, fresh lucerne is more palatable than lucerne hay, and steamed lucerne hay comes between. Professor Henry, in his standard work *Feeds and Feeding*, which the student who desires to thoroughly study this subject should read, says: "Contrary to general opinion, green fodders are no more digestible than the same forage when carefully preserved by drying." This fact is important, because drying is the cheapest method and so easy in our Australian climate. But we have to remember that in drying, very often, especially with such plants as lucerne, a proportion of the finer parts of the plant are lost during the process.

The percentage of ash in plants is small; but it contains the mineral matter necessary to supply the requirements of the animal, and need not be further considered.

Carbohydrates. The meaning and composition of carbohydrate was explained in the chapter on the plant. Sugar, starch, flour, gum, vegetable fibre, etc., are carbohydrates. They contain no nitrogen. They are the source of heat and energy in food, and may be called the heat and energy producers. After digestion they pass into the blood, and in the lungs are decomposed into carbonic acid gas and water, and heat is produced in the process in the same way as when wood is burned.

Fats. The fats of fodder contain the same three elements as carbohydrates, *i.e.* carbon, oxygen and hydrogen, but, proportionately, much less oxygen. They have, therefore, a greater proportion of carbon, and yield more energy when decomposed. They are greater heat-producers than carbohydrates, which explains their value as food for man in the Arctic regions. In calculating the relative energy-producing power of fats as compared with sugar, a pound of fat is considered as being worth about two and one quarter times as valuable as a pound of sugar. In ordinary fodder the percentage of fat is not great, but such materials as oil-cake, linseed, sunflower seeds, contain large quantities. In analyses of foods the carbohydrates and fats are often classed together as nitrogen free extract.

Albuminoids, or proteins. The albuminoids, or proteids, are of great importance in fodders, being called the flesh or muscle formers. We have seen that carbohydrates and fats contain no nitrogen, and the value of proteins lies in the fact that they furnish nitrogen, and also usually sulphur and phosphorus. Nitrogen is essential to the animal economy, and proteids are therefore necessary in fodders. The growth of an animal and its muscular power largely depends on the supply of albuminoids in the food; and fodders which are rich in nitrogen are usually high priced. It should be here noted that both sugar and fat can be formed in the body from nitrogenous foods, so that we have an additional reason for the value of these substances. It is, however, wasteful to use them for this purpose when carbohydrates are so much cheaper.

Nutritive ratio. It has been shown that the carbohydrates and fats go together as heat and energy producers, while the proteids or albuminoids are the providers of nitrogen. These three classes of substances are called nutrients, and a ration is said to be well balanced when they exist in the proportions found by experience to be most suitable for the animal under given conditions. In cold weather more carbohydrates or fats are required than when the temperature is high. It has been found convenient to express the relation between the proteins and the other nutrients in the form of a ratio which is spoken of as the nutritive ratio. Exactly defined it is the proportion or ratio which one part of the digestible protein bears to the corresponding parts of digestible carbohydrates, plus two and a quarter times the digestible fat.

The nutritive ratio of any ration is found in the following manner: First, ascertain the amounts of digestible proteins, carbohydrates and fats it contains. Second, multiply the amount of fats by two and a quarter and add the result to the amount of carbohydrates. Third, divide the result of the second operation by the amount of proteins.

For example, the commonest fodder in Australia is wheaten hay. According to Guthrie, this contains on an average 3.6 per cent. proteins, 46.1 per cent. carbohydrates, and 1.1 per cent. fat, making a total of 50.8 per cent. of nutritive matter. To find the nutritive ratio we multiply the 1.1 per cent. of fat by two and a quarter, making 2.47. We add this to 46.1 and get 48.57, which we divide by the protein 3.6 and obtain 13. So that the nutritive ratio of wheaten hay is 1 : 13, which means that for each pound of digestible protein, or flesh-forming food, in wheat hay, there are thirteen pounds of digestible heat and fat-forming elements.

A ratio is said to be narrow when the proportion of heat producers is small compared to the protein; and it is said to be wide when the proportion is large. Thus, the ratio of lucerne hay is 1 : 3½, which is very narrow as compared with the wheaten hay.

It may be at once asked, which is the better fodder, one with a wide or one with a narrow nutritive ratio?

The answer depends entirely on the purpose for which the fodder is used; but as fodders with a narrow ratio are always rich in nitrogen, and that is the most valuable food constituent, because it is the least plentiful, fodders with narrow ratios are worth more per ton than those with wide ratios. Lucerne hay is worth more per ton than wheaten hay, because of its higher percentage of protein, so that to speak of a food as rich in protein is practically the same as to say it has a narrow nutritive ratio.

It is recognised that animals that are growing rapidly, that are rearing young or are producing milk, wool or eggs, require food richer in protein than do similar animals that are working, fattening, or simply living without gain or loss in weight. In practical feeding it is found that animals have wonderful powers of adapting the food to their uses, so that provided it is palatable, digestible and nutritive, the animal will deal with the ratio in its own way.

The chief object of considering the nutritive ratio of foods is to use expensive proteids economically.

We know that stock thrive well on lucerne, but a study of the ratio shows that using it alone is not economical, for we can supply carbohydrates more cheaply in wheaten hay.

Analysis of Salt Bush by Mr. F. B. Guthrie, Chief of the Chemical Branch Department of Agriculture, N.S. Wales:

	A. nummularia. Grown at Wagga. (Under cultivation.)	A. nummularia. From Bourke. (Uncultivated.)
Moisture,	75·11	56·73
Oil, - - -	·66	·67
Digestible fibre,	8·21	11·59
Woody fibre, -	3·29	3·93
Soluble albuminoids,	·50	1·76
Insoluble albuminoids,	2·56	3·54
Soluble ash,	5·77	14·14
Insoluble ash,	·15	2·04
Chlorophyll, amides, and other extractives (by difference),	3·85	5·60
	100·	100·
Total nitrogen,	·74	1·20
Amide nitrogen, -	·25	·36
Percentage of common salt in ash, -	36·6	56·6

The great difference in the percentage of moisture is due to the fact that the Wagga specimens had not so far to travel, and were more carefully packed.

The following table is taken from a paper by Mr. F. B. Guthrie, Chemist to the Department of Agriculture, New South Wales, and gives the average composition of common Australian dry fodders with the nutritive ratios:

COMPOSITION OF AUSTRALIAN FODDERS.

Fodder.	Water.	Ash.	Fibre.	Total dry matter.	Albuminoids.	Carbohydrates.	Fat.	Total nutrient matter.	Nutrient ratio.
Wheat (grain), -	10·5	1·8	1·8	89·5	11·9	71·9	2·1	85·9	1 : 6½
Oats (grain),	11·0	3·0	9·5	89·0	11·8	59·7	5·0	76·5	1 : 6
Maize (grain),	10·9	1·5	2·1	89·1	10·5	69·6	5·4	85·5	1 : 7¾
Lucerne hay,	8·4	7·4	25·0	91·6	14·3	42·7	2·2	59·2	1 : 3⅓
Wheaten hay,	8·8	4·5	35·9	91·2	3·6	46·1	1·1	50·8	1 : 13
Oaten hay,	10·0	5·0	35·3	90·0	4·5	43·7	1·5	49·7	1 : 10½
Wheaten straw,	9·6	4·2	38·1	90·4	3·4	43·4	1·3	48·1	1 : 13½
Oaten straw,	9·2	5·1	37·0	90·8	4·0	42·4	2·3	48·7	1 : 12
Bran,	11·9	5·8	9·0	88·1	15·4	53·9	4·0	73·3	1 : 4
Pollard,	10·0	3·8	5·2	90·0	17·4	58·0	5·6	81·0	1 : 5
Molasses, -	25·0	5·0		75·0		70·0		70·0	
Cocoa-nut cake,	7·3	5·4	9·7	92·7	17·2	41·3	19·1	77·6	1 : 5
Mangels,	90·9	1·1	0·9	9·1	1·4	5·5	0·2	7·1	1 : 4¼

THE PROPAGATION OF PLANTS.

In nature, plants are reproduced by two methods, the asexual and the sexual. Lowly forms, such as bacteria and many single-celled fungi, are reproduced with marvellous rapidity by the simple process of subdivision. In the higher plants, new generations are usually produced from seed, but not a few also propagate themselves by suckers, layers, and by detached branches or twigs, which take root and grow. A willow branch, broken by an animal or the wind from the parent tree, will, if it falls into the mud, take root even if upside down.

The farmer, fruit grower, or gardener by his skill improves nature's products until they may almost be said to be artificial, because without his constant care and protection they become a prey to disease and adverse conditions and die out. The wild oat is always fighting the farmer for a place in his fields, and his efforts are equally constantly directed to its suppression, so that it will not choke out his more valuable and more productive but less hardy crops. The wild plum and pear will fill the orchard with suckers which will crowd out the valuable commercial varieties. The wild dock will smother its relative, the huge, succulent, edible rhubarb. Examples might be multiplied indefinitely, but these are sufficient to impress on the student the fact that the special plants which constitute the crops of the farmer, fruit grower, and gardener are highly developed, specialised products of man's care and skill through unknown ages. The origin of many cultivated plants is quite unknown. For example, we are by no means certain what was the original progenitor of wheat. It has been developed for its seed, and one acre will produce enough seed for forty acres; but leave a field of wheat to itself, and in a few years it will die out, or rather be choked out with weeds.

Some varieties of plants have been developed until they have almost lost the power of producing seed. The banana is an example. Seeds are a drawback to the banana fruit from man's point of view, and so, mutations which do not have seeds have been propagated by suckers for centuries. In the same way we artificially reproduce seedless orange trees, have developed cucumbers in which most of the seeds are undeveloped, and were it possible to reproduce them we would soon have perfectly seedless varieties. There are a multitude of abnormal plants in cultivation which would die out in a generation but for man's constant care. The navel orange, the currant vine, the sultana grape, and the highly prolific varieties of potatoes are common examples.

Propagation by seed. In propagating plants man usually follows nature's methods, the most general of which is by seed. A seed consists of:

(*a*) The embryo plant, and

(*b*) A store of nutriment to feed the developing embryo until it is able to support itself.

Such crops as wheat, maize, oats, barley, rye, rice, peas, beans, nuts and so forth, have been developed so that the store of food intended by nature for the nourishment of the embryo plant has been largely increased in amount, and often improved in character, so that it will be better adapted for human food. This work is still going on. In America the plant breeding stations are materially altering the character of many varieties of maize. Some are being bred with increased starch content, while others are being developed for richness in nitrogen. The late Mr. Wm. Farrar, of New South Wales, and other wheat breeders of Australia, have by cross breeding originated varieties of wheat which not only yield heavy crops of grain but possess special chemical characters rendering them more valuable for milling and bread-making. This is man's work. Nature's object in providing seed is merely to secure the survival of the species.

There are so many excellent Nature Study books and works on elementary agriculture, with chapters dealing in the most simple and complete manner with the growth of seeds, that it is quite unnecessary to go into details here. It is necessary for the grower to remember that, in the practical commercial production of wheat, oats, barley, maize, peas, or other farm crops, or of fine onions, cabbages, cauliflowers, tomatoes, melons or other vegetables, the character of the plants he grows will primarily depend on the seed he sows.

Germination. The chief factors which influence the germination of seeds are:

(*a*) The condition of the parent plant, *i.e.* its healthiness, vigour and suitability of the conditions under which it grew. Some plants appear to thrive well under climatic conditions where they will not produce good seed. This fact is recognised by the big firms of seed growers and merchants.

(*b*) The method of preservation. This depends somewhat on the kind of seed, but, as a rule, seeds kept in dry air-tight tins or bottles and in the dark retain their vitality longer than when exposed to air and light. Moisture and extreme dryness, as a rule, shorten the period of vitality of seeds.

(*c*) The character of the seed itself. Some seeds are specially provided with tough waterproof coats, which preserve their vitality for very long periods.

(*d*) The age of the seed. Some seeds, like those of the parsnip and onion, are not reliable when more than one season old, others, like the seeds of the various Australian acacias ("wattles"), retain full vitality for an indefinite number of years, up to forty or fifty or more. Most agricultural seeds retain their full germinating power for a few years only, and seed of the previous season is nearly always to be preferred. There are exceptions. Many gardeners think that cabbage seed gives the best results when two years old, and prefer melon seed to be two or three years old. The writer has grown both sweet and water melons each year for ten years from the same packets. The oft told story of wheat grown from a few grains found in a mummy case in Egypt is not authenticated.

It is not wise to use seed wheat more than three or four years old. The writer sowed four varieties of wheat, obtained from an Odessa miller in 1896, each season on to 1906, in which year not one grain grew.

Given good seed, satisfactory germination will depend on favourable conditions of soil, moisture, warmth and the proper supply of oxygen. These matters have been considered in connection with our study of the soil.

When seeds possess very tough outer coats, it is often a good practice to soak them for a time in warm water. Care must be taken not to continue the process too long. To soak a short time and then wrap in damp flannel or canvas, and keep them in a warm place, is a safer plan. Some seeds, like wattle seeds or the seeds of Sturt's pea, may have boiling water poured over them, or they may be actually boiled for a minute or two to secure rapid germination. Seeds must not be planted too deeply. The smaller the seed the less deeply it should be planted. The looser the soil the more deeply may the seed be covered with safety. For the best germination many practical gardeners have a rule, "Cover a seed with soil no deeper than its own length." This is not practicable in farm operations, especially in our dry climate, but much seed is lost through being covered too deeply. Seed, like that of rape and lucerne, is best merely rolled into the soil or covered with a brush harrow.

Some seeds have the power of re-germinating. Farmers are familiar with this quality in wheat, which may start, be dried off by a spell of warm, dry weather, and then come again when favourable conditions occur. Professor Bailey states that "some seeds have been known to resume germination five or six times, even when the rootlet had grown half an inch or more, and the seeds had been thoroughly dried after each re-germination."

Importance of pure good seed. The good farmer or gardener takes great pains in preparing the ground for the sowing of the seed which is to produce his season's crop. He sows his seed at the time experience tells him is most likely to produce the best results. If it fails to germinate his season is wasted. Supposing the seed germinates well he has many weeks or many months to wait for the maturity of his crop, and during all this time it is liable to damage from insect and fungus pests and diseases, adverse weather conditions, such as too much or too little rain, frost, and so forth. He is never sure of his crop until it is harvested, and then he has the problem of marketing. But even when the conditions are all favourable he may have all his hopes shattered by finding that the seed was not pure, or the variety was bad. His onion seed may germinate well, but the plants may run to seed. The cabbage plants may start all right, but may prove comparatively worthless. He may buy supposed lucerne seed, and a large proportion of the plants may prove to be clovers and trefoils, or the field may be infested with dodder. He may desire to grow clean seed wheat on a clean field, and find his crop mixed, and of twenty per cent. less value, because the seed he had purchased as pure was not so. He may have bought seed of an early wheat, say bunyip, expecting to be able to reap it early, but, because of a proportion of late sorts mixed with it, his plans for harvesting may be upset, and part of his crop may be destroyed by a storm.

The above are a few of the unnecessary troubles which may be avoided by care in securing pure good seed. The Federal and State Governments can, and should, do much to protect the producer. All seeds imported and offered for sale in quantity should be examined for purity and tested for vitality. Much can be done in this way; but nothing that a Government can do can protect a gardener from badly grown onion or cabbage seed, or a farmer from mixed seed wheat. In such matters the only safeguard is either to grow the seed or buy it from known and reliable men. While we cannot teach a man to farm from a book, it is possible to point out the importance of matters like this, and save the farmer from much unnecessary loss. No wise farmer or gardener, on any consideration whatever, will buy cheap seed. The best is the cheapest, whatever the price. We do not mean that the most costly is always the best, because the high price may be merely due to the popularity of a special variety which has been well advertised. It is a good rule to stick to well-tried varieties which have been found reliable, productive and suitable to one's conditions. Always be ready to experiment, but never rely on advertised qualities or on one season's results.

The testing of seeds. Much annoyance, loss of time and expense may be saved by testing the germinating qualities of seeds before purchasing, or, in the case of seeds saved on the farm, before the time for sowing. When asking for quotations for such seeds as rape, lucerne, clovers, or any seed to be sown in quantity, a sample should be secured and tested in the following manner: Saturate several thicknesses of heavy blotting paper or pieces of calico, and fit them into the bottoms of plates or other suitable vessels. Count out 100 average seeds of each sample and distribute them over the paper or calico. Cover each plate with a sheet of glass and keep in a warm place. See that the paper or calico is kept just nicely moist. Watch carefully and note: 1, How soon the seeds begin to sprout; 2, Do they germinate evenly; 3, The percentage of seeds that grow. Good seed will germinate quickly and evenly with few failures.

Examine for purity. A little practice and very careful observation will make the farmer or gardener familiar with the characteristics of each variety of seed, and it will pay him to study this matter in connection with any kind of seed he is depending on for a staple crop. Lucerne seed should always be examined with a lens, and a sharp look out should be kept for dodder. Any new sample of seed should be carefully examined to see whether the type of grain is uniform. So much depends on seed that it is a sound principle to adapt the old saying to read, "Test and try before you buy."

Seed required for an acre of ground. The following quantities of commercial seeds required to sow or plant an acre of ground are those usually advised. In considering them it is necessary to remember that the farmer as well as the gardener finds it advisable to sow at least four times the quantity actually necessary. He does this to provide for various contingencies, such as: Defective seed; too deep or too shallow planting; unfavourable conditions; loss from pests of various kinds, and other contingencies. Thus the usual quantity of seed wheat used throughout Australia is about one bushel per acre. This is the result of practical experience, but it is theoretically from four to six times the actual requirements. Ten pounds of good sound wheat will provide on an average quite 100,000 seeds, and after allowing 12 per cent. of failures, these will provide two plants for every square foot of surface, and with a fair stooling variety this is more than will properly mature in a good deal of our wheat country under normal conditions. It is all right to plant a plot with this proportion of selected seed when the conditions are such that each seed may be fairly expected to grow and mature; but under ordinary conditions the wheat grower should stick to the practice proved by experience to give the best average results. In the case of vegetable seed, even greater allowance has to be made for contingencies, and the table forms a fair guide for the inexperienced.

Barley, 1½ to 2 bushels.
Beans, broad, 2 bushels.
Beans, French, 1½ bushels.
Beet, red, 5 to 6 lbs.
Cabbage, for transplanting, ¾ lb.
Cabbage, cattle, in drills, 5 lbs.
Carrots, 3 to 4 lbs.
Cauliflower, ¾ lb.
Clovers, 12 to 15 lbs.
Cucumber, ¾ lb.
Grasses—Rye, Cocksfoot, or mixed, 1½ to 2 bushels.
Hungarian Millet, 20 lbs.
Kohlrabi, 4 lbs.

Linseed, 1½ bushels.
Lucerne, for pasturing, 5 to 10 lbs.
Lucerne, for cutting on moist lands, 15 to 20 lbs.
Maize, 1 to 1½ bushels.
Mangel, 4 to 8 lbs.
Melon, water, 1½ lbs.
Melon, rock, ¾ lb.
Oats, for hay, 2 bushels.
Onion, in drills, 3 lbs.
Parsnip, 5 lbs.
Pearl Millet, 4 lbs.
Peas, garden, 2 bushels.
Peas, field, 2 bushels.
Potatoes, 7 to 10 cwts.
Pumpkins and marrows, 2 lbs.
Rape, 3 to 4 lbs.
Rye, corn, 2 bushels.
Sorghum, 12 lbs.
Sunflower, 6 lbs.
Tares, 2 bushels.
Tobacco, 1 oz.
Turnips and Swedes, 3 to 4 lbs.
Tomatoes, for transplanting, 2 ozs.
Wheat, ¾ to 1½ bushels.

Table Showing the Customary Weights per Bushel of Farm Seeds.

Barley, 50 lbs.
Beans, 60 lbs.
Clover, 60 lbs.
Most grass seeds, 20 lbs.
Linseed, 56 lbs.
Lucerne, 60 lbs.
Maize, 56 lbs.
Oats, 40 lbs.
Peas, 60 lbs.
Rye, 60 lbs.
Sorghum, 40 lbs.
Tares, 60 lbs.
Wheat, 60 lbs.

Other methods of propagation. Some varieties of cultivated plants either do not produce seed, or produce them so sparingly, that other methods of propagation have to be adopted. Most of our best sorts of fruits and many garden plants are either bud variations or "sports," or are the result of cross breeding and do not come true from seed. In other cases the propagator desires to secure more rapid maturity than can usually be got from seed. In such cases plants are propagated by (*a*) subdivision; (*b*) suckers; (*c*) layers; (*d*) cuttings; (*e*) grafting and budding.

These operations are best taught by practical demonstration. Apart from this fact, they are chiefly connected with the different branches of horticulture, and are fully described and illustrated in horticultural books, as well as in bulletins issued by the various Departments of Agriculture. All that is necessary here is to explain that all these methods of propagation are really subdivision of the parent plant. All the tens of thousands of trees of the Dunn's seedling apple, often called Munro's Favourite, are essentially parts of a chance seedling raised by Dunn, a gardener employed by the late John M'Ewin, of Glen Ewin, South Australia, in the early days of that State. Mr. M'Ewin imported some apples from Tasmania, and gave some to Dunn on condition he planted the seeds. One of these seeds produced all the Dunn's seedling apple trees now in existence. In such cases the roots of other trees are used to facilitate the work of propagation; but with some plants, such as vines, every new plant is grown from a cutting, essentially a part of an older one, until we get back to the original seedling or sport.

The potato an example of propagation by buds. Special reference should be made to the potato in this connection. It is the custom to speak of the potato sets as seed. They are no more seed than is a vine cutting. The seed of the potato plant is in the "potato apple" or fruit, which matures occasionally as a result of a fertilised flower. A seed from a potato fruit may produce a seedling plant having valuable characters. Such a plant may be propagated as a named market variety and become widely grown. All the millions of plants, producing thousands of tons of that variety, are simply multiplications of the one parent plant, and are produced from buds of the original seedling. It is both interesting and important to clearly understand this fact, because on it depends the answer to the question, why varieties "run out," *i.e.* why varieties which become popular because of their profitable characteristics gradually lose them and are discarded.

To understand the problem, we must consider the structure and habits of the potato plant. The seedling grows, as does any other seedling, producing a root system, stem, branches and leaves. It may or may not blossom or produce seeds ; but, under cultivation, as a rule it does not. At the proper stage of development, a number of underground branches grow out from the stem, and on these tubers or potatoes form, containing stores of nutritive materials, chiefly starch, intended for the nourishment of next season's tender growth. It is important to remember that tubers do not grow on roots, but on underground branches of the stem.

The tubers are provided with buds, which we commonly call eyes, and really correspond to cuttings or buds with stores of nutritive material for their future nourishment. The plant dies down and in due time starts new growth from the buds, the nutritive material simply serving to nourish the young growth until it forms a new set of roots and leaves to carry on the functions of nutrition. In the wild potato the tubers were small. In the cultivated varieties they have been enormously developed. Under ordinary careless methods, the potato grower sells the tubers from his best plants, and uses the inferior ones for "seed" for his new crop. Is there any wonder that a variety deteriorates?

In this argument, the question of the importance of imparting strength of constitution by occasional cross breeding is not considered, because that is the plant breeder's work. What we wish to do is to impress upon the propagator of plants, by the various methods of subdivision, the importance of continuous selection of the most vigorous disease-resisting and productive specimens for his buds, grafts, cuttings and so forth. It is not too much to say that the average yield of potatoes could be increased from 25 per cent. to 30 per cent. by attention to this simple but very important detail. Every potato grower should each season select the very best, that is, the most prolific and otherwise most desirable, plants in his field and save the potatoes for planting. No matter what they may be worth for market purposes, they will be worth more for producing a crop. On no account should the potatoes from weakly non-prolific or otherwise poor plants be used for planting. Small potatoes from prolific plants may be used, and when a prolific plant has failed to produce large potatoes on account of lack of moisture the tubers may be excellent for sets. Each year the tubers, from a few of the very best plants in every sense, should be kept separate, and each lot planted separately in special plots. The resulting product of each one of the plants should be compared, and the tubers from the best of the plots kept separate for a special strain, while the rest are used for planting in the general crop.

Such work of course involves some trouble and takes some time, but it is more expensive to omit it than to do it. The grower cannot control seasons, but he can so regulate his operations as to get the best from either a good or a bad one. The same principle applies to other crops; but the writer has selected the potato as an example, because, in no Australian crop is there a greater annual percentage of loss due to careless methods, and because he has practically tested the plan suggested and knows that it will work out in the way indicated. No words are too strong to denounce the general unbusinesslike, foolish policy of selling the best and propagating from the inferior plants; or, even worse, buying a "change of seed" from some one who is acting in the same way. A change is only desirable when something better is obtained.

Improving wheat by selection. Wheat breeding is a specialist's work, while the farmer's business is to grow crops and secure the greatest possible return from the least outlay. Therefore, unless a farmer finds pleasure in the work he had better leave crossing, selection and the growing of pure seed to those who make a speciality of it. Space will not permit of a discussion of the principles of selection, which are clearly explained in Professor De Vries' excellent work, *Plant Breeding*. What we wish to do is to explain, as clearly and as concisely as possible, how the farmer, willing to take the trouble, should proceed in the practical work of selecting the best pure types of the commonly-grown varieties found most suitable for his particular condition. The yearly loss from growing mixed inferior seed on Australian farms is

A 32 Bushel Crop of Square Head Wheat on Virgin Forest Land.

"Scratched" (worked with a spring tooth cultivator) and drilled with 56 lb. superphosphates. Western Australia.

enormous, certainly amounting to a million sterling a year. If the farmer goes no further, he should at least grade his seed wheat and sow only perfect well-developed grains. But he should do more. He should either take the trouble to specially grow pure seed or contract for his supplies with a reliable farmer in the district, who makes growing pure seed wheat a speciality.

There is no need to procure seed from a distant district. The old idea of the advantage of a " change of seed " has been proved to be erroneous when subjected to exact test. Of course, good seed from another district is better than poor seed grown on one's own farm or neighbourhood, but, given seed of equal quality, the local seed is more likely to give good results than that from a locality far away, and having a different climate. There is no need for varieties to run out.

Selecting pure types. All work in connection with growing pure improved seed should begin with individual plants. This is the fundamental principle. The product of each one of these selected plants should be kept separate from the beginning to the end. In this way only can an absolutely pure strain be secured. The old plan, still frequently recommended, is to select enough fine ears from a crop to produce a bushel of graded seed with which to sow an acre of clean land. From this acre enough of the finest ears are again selected to produce a bushel of graded seed, while the balance is used for sowing a special field to produce seed for the main crop. Each year the process of selection has to be continued, and, without doubt, the result is a vast improvement in the yield, and in the end it produces a fairly even type by the elimination of the unlike. It is a laborious, tedious method, wrong in principle. By actual test, the writer found that it required between eight and nine bushels, by measure of wheat ears, to produce 65 pounds of grain, which would grade down to a bushel or less of graded seed. This means that the farmer must gather three sacks, or say, 10,000 selected ears, hand thresh them, hand clean and hand grade that quantity each season, to keep up his selection work, and in the end is not likely to get a pure strain.

The pure pedigree system. Dr. H. Nilsson, Director of the Swedish Agricultural Experiment Station at Svalof, and Willet M. Hays, of the United States Department of Agriculture, have demonstrated that the old method was wrong in principle, and have worked out more simple, as well as perfectly reliable, methods of accomplishing the object in view. Nilsson's method is fully explained in De Vries' work, *Plant Breeding*. In the same work Hays method is outlined, and it is set out in detail in Bulletin 62, Agricultural Experiment Station, Minnesota, 1899. We will not deal with it further than to say that, having selected a considerable number of types, Hays sowed selected seeds of each plant separately, and judged their value by the yielding capacity in the next generation of one hundred selected grains.

Nilsson started on the old plan and found it failed to secure the purpose sought. He discovered that varieties are neither pure nor uniform, but that, in any field of a given variety, there will be found a great number of strains or elementary forms. He proved that the true method of improvement was the selection of single excellent individual plants, and that, if not hybrids, they will yield a constant and uniform progeny. The method had been used long before by several Englishmen, but it was not recognised as a principle. Nilsson proved that, having made the right initial selection of the best single ear, further selection from the progeny was unnecessary, for the uniformity was such that another selection was simply impossible. All that was afterwards necessary was to keep the isolated type free from accidental admixtures and multiply as rapidly as possible. Occasionally a single specimen will sport and deviate from the main type. Any such plant should be separated, and, if good, be tested by itself. Accidental hybrids may also rarely occur and may give rise to valuable new strains.

The practical application. A practical application of Dr. Nilsson's method, suitable for the interested practical farmer, may be outlined as follows :

At harvest time select a few of the finest plants in the crop, taking the whole plant in each case. In making this selection the farmer should be guided by practical considerations only. The selected plants should possess as many as possible of the qualities desired in a good profitable wheat. To merely select the finest ears may be far from securing the most prolific strain, because these fine ears may be the product of plants having only one or two stalks. Free stooling is not a characteristic of early varieties such as are necessary for districts with a short rainfall, but it is a desirable quality provided that, in securing it, others are not lost. One ear may have 100 grains, but, if that is all the plant produced, it is by no means as prolific as a plant with five ears averaging 60 grains. The oft-recommended plan of selecting enough of the finest typical ears takes no account of other characters, and may easily result, for example, in the production of poor tillering strains. It may be that a strain, averaging two good ears, possesses qualities rendering it of special value, our present point being merely to emphasise the fact that merely to select for large typical ears is not sufficient.

In considering the qualities most desirable in the plants to be selected, each farmer will have to take into consideration the requirements of his own district, or, it may be, of his own farm. Heavy yielding is the first consideration, provided it is not discounted by accompanying undesirable qualities. As a farmer will only, as a rule, select from a variety proved generally suitable for his conditions, his task is to select the plants from that variety which, in his practical judgment, possesses the desired qualities above the average. In an early variety no selected plant should be later than the average, and, if earlier, so much the better. It should be prolific, have strong straw which will not go down where growing vigorously or break with the wind when ripe. The ears should not only be large and full but hold the grain well. As a rule the plant with the largest number of large fully-developed ears, other qualities being present, is the one to select. In selecting such plants it is important to see that they are growing under normal conditions in full competition with their fellows.

Having made the selections, they can be compared and a re-selection made. The five or ten best should be placed in order, the ears should be cut off, rubbed out, imperfect grains discarded and the balance put in an envelope, tin or bottle, labelled like this,—Federation, No. 1 Selection, 1912, and so on up to five or ten. The product of each plant should be sown in a plot by itself. For very special work, the best grains from the best ears of the best plants only may be sown, but to take the whole product of a plant is a much more rapid process, and normally the whole of the progeny will have the characteristics of the selected plant. Careful inspection of the plots will show which of the five or ten selected strains has the greatest value, and this is the plot to be chosen for rapid propagation.

After the five or ten best plants have been selected for individual test, the balance may well be threshed out and the seed used for a general plot, to secure quick return of good selected mixed seed. Suppose only five special plants were kept separate the farmer would have six plots, five small ones and one large one. The second season if he found, as he almost certainly would, that one of the five possessed special merit, he could mix the progeny of the other four with that of the large plot for improved mixed seed. The man who takes an interest in the improvement of wheat will naturally continue to make selections each year; but our purpose is to avoid making the work appear too tedious. The plan outlined will be found to give definite profitable results in accord with the most modern principles; and, at the same time, necessitates less trouble than that usually recommended.

Application to other crops. The same principle of selection applies equally well to any self-fertilising crop, such as oats, barley and rye; but it does not give the same results in connection with plants which are cross fertilised. Work of this nature is urgently required in connection with the varieties of oats commonly grown in Australia It is also important that it should be done in connection with field peas. Tedin's work, as outlined by Professor De Vries, shows that there are immense possibilities in various directions. The value of the pea crop is very little appreciated by Australian farmers, except in Tasmania and a few of the districts of the mainland. The plant grows well over a very considerable extent of the wetter wheat areas; but its fruiting is unreliable. The work done at Svalof indicates that there is no reason why varieties should not be selected from those in cultivation which would prove reliable croppers where the pea is now supposed to be an impossible crop. When the value of the pea crop as a soil renovator, and as a feed for sheep in the dry summer months is considered, the value of such work is seen. There is no finer field for profitable work of a national character than in connection with this crop. Tedin has been able to distinguish 500 different strains of peas which have proven constant in his pedigree culture, and out of such a number is it not probable that at least one will prove suitable for our wheat areas?

Association of characters. In connection with the work of selection of the best strains of valuable farm crops, a few words should be said in explanation of a principle which has only recently been discovered; but which is all important in connection with the work of plant selection. De Vries says: "Experience has taught that qualities are often associated with one another by distinct laws, and that a knowledge of these laws may give us a power over them, greater than any man has hitherto aspired to."

This association of characters is well known to stock-breeders. The horse judge considers the animal's head, because he knows that certain characters there indicate qualities in the animal which he desires it to possess. A still more striking example of the principle is the importance which the selector of dairy cattle pays to the size and character of the escutcheon as an indication of milking qualities.

Luther Burbank, the great Californian plant breeder, owes much of his success to his being able to see the relation between characters in the foliage of his seedlings and what he expects in the flowers and fruit. The ordinary gardener must wait for the plants to mature. Burbank makes his selections by an intuitive or accumulated experience. Nilsson has discovered that he can select varieties of cereals which will have a desired quality, because they possess some peculiar character which indicates the hidden one he is looking for. For example, he desired to obtain a variety of malting barley sufficiently strong in the straw to resist unfavourable climatic conditions. He worked for years endeavouring to improve recognised varieties of Chevalier barley and failed. A minute study of the botanical characters of other sorts of strong straw barleys led him to discover a relation between the forms and hairiness of the ears, spikelets and scales, and the desired qualities in brewer's barley. He examined tens of thousands of strong barley plants, and selected some sixty with the related characters for comparative trial. After several years of testing, keeping each pure, he selected one of these which best combined the qualities of fine brewer's barley with strong straw. From this one plant a new race of brewing barley, called Primus barley, has been developed, and is now very widely grown in Sweden.

Professor De Vries shows that " insignificant characters or organs may show us the way and guide us in our selection." In all this work of selection the essential point is that any commonly-recognised variety of farm crop, say the dun pea, Algerian oat, Cape barley, and purple straw wheat, " really consists of numerous elementary species which are quite distinct from one another." It is the business of the agriculturist to select from these those best suited for his purpose and breed pure strains. The individual plant is the only basis for so doing, and a close study of one set of characters may guide him in selecting rightly the individual possessing other desired characteristics.

PRINCIPLES OF BREEDING.

Genetics. Genetics is a comparatively new word coming into general use largely as a result of the spread of the principles of Mendelism. "It is the term applied to the experimental study of heredity and variation in animals and plants, and the main concern of its students is the establishing of law and order among the phenomena there encountered" (Punnett). It is altogether too vast a subject for anything but the most rudimentary treatment; but a modern text book on the principles of agriculture would be incomplete without an endeavour to give the student a clear, if elementary, idea of Mendelism, and its bearing on the practical work of the stock-breeder and farmer.

The stock-breeder's interest in the laws of heredity is known to all, but it is not generally recognised that wheat farmers, fruit growers, and by no means least, horticulturists are also dependent on the same principles for improvements in their crops. Plant breeding, like stock breeding, is and will always be a special department of the science and practice of agriculture depending for success on particular aptitude which is an inherited quality; but which, like other characteristics, must be developed. Given the natural aptitude, success will depend on training and a knowledge of the laws of heredity as far as they are known.

The famous stock breeders, such as Bates, Booth and Bakewell knew nothing of Mendelism ; but they had an intuitive insight which, coupled with experience, led them to apply some of the principles. The same may be said of the plant breeders, including Luther Burbank, who have enriched the world by producing more beautiful and more useful varieties of plants. The old method, which is still the general custom, was to improve crops and animals by selecting the best individuals for breeding purposes. For the ordinary farmer the importance of this method cannot well be over-estimated. It does not produce anything new, but it eliminates inferior strains and preserves the most profitable. It does more than this, for it secures the permanency of any valuable mutation which may at any time occur in a herd, a flock or a crop.

Mutations. Darwin taught that there is constant variation in the animals and plants classed as one species, that a variation giving an individual a special advantage over its fellows in the struggle for existence was most likely to survive and propagate its characteristics, and so very gradually new varieties arose, and from these new species would be developed. The process was supposed to be very gradual. De Vries has shown that pronounced variations arise suddenly and are permanent. These he calls mutations. Many of our garden varieties of plants have arisen in this way, and there is no doubt that it is to this law that we owe many strains of our domestic animals. In common language such mutations are called sports, and one is tempted to discuss the matter at length. Space forbids, but it may be laid down as good general advice that the stock breeder, wheat grower, general farmer, fruit grower and gardener should always be on the look out for mutations possessing apparent valuable characters, and should test their value. Some years ago the writer, in inspecting a block of Rome Beauty apple trees, noticed a bud sport, or mutation, on one tree which had given rise to a small branch bearing apples, typical of the variety in every way but one. The eight apples on this branch, instead of being streaked with red, were all a deep rich red colour. The branch was marked, an old tree was cut down in the season and grafted with wood from the branch, and when it came into bearing the red character came true. The apple is now on the market as a commercial variety. There is little doubt but that the currant and sultana seedless grapes, navel oranges, and other commercial varieties of plants originated in this way generations ago. The law holds good with stock, and many of our noted strains owe their origin to a particular sire with specially valuable and prepotent qualities.

Cross breeding. Cross breeding among domestic animals has been practised from time immemorial, mules being mentioned in the early pages of history. When the cross is between two animals so distinct as to be recognised as species, the progeny are known as hybrids, and are often barren. Indeed the power to interbreed and produce fertile offspring is recognised as the correct test between varieties and natural species. When the cross is between varieties or breeds of the one species the offspring are crossbreds. In domestic animals and cultivated plants the distinction between species and varieties or breeds is much less clear than among those not brought under the control of man, and the terms, hybrid and crossbred, are so often used interchangeably that it seems practically useless to try to make a distinction.

By cross breeding and subsequent careful selection new strains of the various breeds of domestic animals and varieties of plants have been produced possessing the more valuable characteristics of the original parents.

Male and female germ cells. The reproduction of animals and plants is a wonderful, and in some respects still a mysterious process; but it may be definitely stated that there is no essential difference between animals and plants, so far as the main principles of reproduction are concerned. In every typical case the germ which produces the new life is formed by the uniting of what are commonly called male and female cells. In the case of plants, the female cells are the ovules which are to be found in the ovary below or in the centre of a flower, and the male cells are contained in the grains of pollen with which every reader is familiar as the yellow powder contained in the little club heads of the stamens of the flower. The corresponding cells among animals are the ovum of the female and the spermatozoon of the male.

When a suitable male and female cell come together under favourable conditions, they unite and combine into one new cell, which is the beginning of a new life. In the case of birds and reptiles, the mother provides the embryo thus formed with a supply of nourishment sufficient to support it in the early periods of its development; and the embryo with the food supply enclosed in a shell or tough skin is known as an egg. In the case of plants the mother plant provides the embryo with a supply of nourishment and encloses it in a protective coat, and the result is called a seed. In mammals the embryo is parasitic upon its mother during the early stages of its growth, and it continues to so live until sufficiently developed to maintain a separate existence. It is important to remember that the seed of a plant, just as much as the egg of a bird, is a new generation, only wanting sufficient time and suitable surroundings for its development. The beginning of the new generation is the uniting of the male and female germ cells.

Gametes and zygotes. The separate male and female cells which are capable of uniting to form the beginning of the new generation are called gametes, or marrying cells. The female gametes are called ovules when they belong to plants, and ova when they belong to animals. The male gametes are called spermatozoa when they belong to animals, and pollen grains when they belong to plants. When the gametes are fused or yoked together into a new cell the new individual is called a zygote.

It will be noted that, as the zygote arises from the fusion of two separate gametes, the new life so formed must be regarded as of double structure. This is important, because in connection with the Mendelian conception, when the zygote in its turn comes to form gametes, the partnership is broken and the process is reversed. Professor Punnett says: "The life cycle of a species from among the higher plants or animals may be regarded as falling into three periods: (1) a period of isolation in the form of gametes, each a living unit incapable of further development without intimate association with another produced by the opposite sex; (2) a period of association in which two gametes become yoked together in a zygote and react upon one another to give rise by a process of cell division to what we ordinarily term an individual, with all its various attributes and properties; and (3) a period of disassociation when the single structured gametes separate out from that portion of the double structured zygote which constitutes its generative gland."

Mendelism. What is familiarly known as Mendelism is simply the explanation of the results produced by cross breeding. The word is a deserving memorial of the work of Abbot Gregor Mendel, who discovered the governing principle of cross breeding and published it in 1865. It remained unknown to the world until 1900, when De Vries and two other investigators published papers giving the substance of Mendel's long forgotten treatise and confirmed it by their own experience. Professor Bateson published it, with modification, in 1902, and he is to-day the leading English exponent of the great discovery. What is here said is based on his work, *Mendel's Principles* *of Heredity*, published in 1909, and Professor Punnett's more popular book, *Mendelism*, to which the reader desiring further information is referred. Mendel's Laws have explained some of the hitherto obscure results of breeders, and are without doubt destined to exercise a powerful influence on the practice of breeding of plants and animals. In connection with plant breeding they have already done wonders. Instead of taking from ten to twenty years to fix a type of cross-bred wheat, Professor Biffin of Cambridge has proved that the work can be done more certainly in three or four generations.

In the case of animals, while remarkable results have been achieved, the slowness of breeding and the complexity of characters render it necessary that many years must pass by before working laws are elaborated. All that at present can be stated with certainty is that Mendel's Laws do explain many facts which have hitherto been a puzzle, and promise in time to replace fair certainty for mere guesswork.

There are three important principles involved in Mendelism, which are sometimes called Mendel's Laws:

1. **The law of dominance.** Mendel worked out his theory by cross breeding peas. He found that if he crossed tall peas with dwarf peas, the progeny were all tall. This generation is now called F.1. From the fact that tallness obliterated dwarfness in this first cross Mendel called it the **Dominant** character, and because the dwarf character was hidden he called it **Recessive.**

The tall pea plants of the F.1 generation were allowed to produce seed by self-fertilisation. All the seeds were carefully saved and when sown produced the F.2 generation. These invariably proved to be mixed. This fact is familiar enough, but Mendel carefully classified them for tallness and dwarfness and found that there were three talls to one dwarf, or 75 per cent. dominants and 25 per cent. recessives. It must not be overlooked that he was dealing with two easily recognised characters.

These were again allowed to fertilise themselves and the offspring of each plant was sown separately. **Sowing the seeds of each plant by itself is the important point in practical work in cross breeding.** This generation is called F.3. Mendel found, and his results have been checked by hundreds of others, that the seeds of the recessives of the F.2 invariably produce recessives in F.3 generation, and they continue to do so in succeeding generations, in other words they are pure bred in regard to the particular character being considered.

In the case of the dominants of F.2 the case was different. When the seeds grew it was found that in the F.3 generation the progeny of some of the F.2 talls (or dominants) produced talls only, and continued to do so in the following generations. In other words, some of the talls of the F.2 generation bred true and some did not; and calculation showed that the proportion of impure to pure was two to one. The two-thirds of the tall or dominants of the F.2 generation which did not come true produced talls and dwarfs in the proportion of three to one in the F.3 generation. The dwarfs, or recessives, of this generation continued to breed true, while the talls, or dominants, repeated the process in the succeeding generations.

Therefore, the whole of the F.2 generation, produced by self-fertilisation of the original crossbreds, consisted of three kinds of plants:

25 per cent.	50 per cent.	25 per cent.
Pure dominants.	Impure dominants.	Pure recessive.

$$\text{or}\quad \underbrace{\text{Pure dominants.}\qquad\text{Impure dominants.}}_{\text{3 dominants}} \quad : \quad \text{1 recessive.}$$

"The result is just what would be expected if both the male and female germ-cells of the cross bred F.1 were in equal numbers bearers of either the dominant (D) or the recessive (R) character, but not both. If this were so, and if the union of the male and female germ-cells occurs at random, the result would be an F_2 family made up of

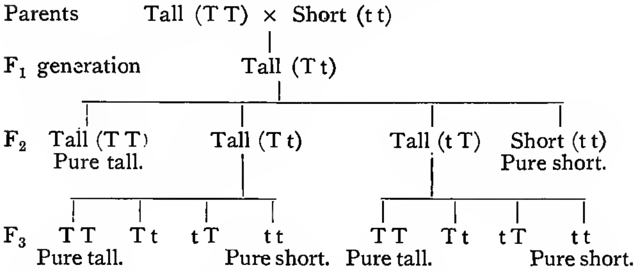
$$\underbrace{25\,DD \;:\; 25\,DR \;:\; 25\,RD}_{3D} \;:\; 25\,RR$$

$$3D \;:\; 1R.$$

But, as the first cross showed, when D meets R in fertilisation the resulting individual is in appearance D: therefore the F_2 generation appears as 3D to 1R. The results of the F_3 generation are in exact agreement with this suggestion: for the R plants produce R only: and of the D plants one-third give D only, while two-thirds appear as dominants; but when grown in the next generation again produce the same proportions of D and R.

The recessives always come true, and one-third of the dominants also come true, while two-thirds of the dominants are the same mixture.

The result is represented diagrammatically thus :



The same result follows in each succeeding generation. The pure talls (T T) and the pure shorts (t t) come true : and the mixtures continue to give the results above shown.

2. **The law of segregation.** From the above observations, which were repeated in regard to various pairs of distinct characters, Mendel concluded that the male and female germ cells of the F.1 generation were bearers in equal numbers of either the dominant or recessive characters, but not of both. The fertilised ovum, or zygote, formed by the original cross, was made by the union of two germ cells or gametes bearing respectively tallness and dwarfness. Both these elements entered into the composition of the original F.1 zygote ; but if the germ cells which that zygote eventually forms are bearers of either tallness or dwarfness, there must, at some stage in the process of the formation of the new germ, be a separation of the two characters.

This phenomenon, the separation of the characters from each other in the course of the formation of the germs, is called segregation. This fact was the essential discovery which Mendel made, and it is now known to be one of the normal phenomena of nature. It is the foundation of heredity. Knowing that each male and female germ is complex, and contains a number of unit characters, we are able to realise that when these are united into one which develops into a new life, its nature will depend on the segregation or re-arrangement of the original units. The "Law of Dominance" led to the discovery of the principle of segregation which explains it; but the dominance of certain characters is not an essential principle of Mendelian heredity. Segregation always applies even when there is no appearance of a dominant characteristic. It is recognised that sometimes a character may behave as a dominant and sometimes not, and that we are as yet only on the threshold of understanding the working of the principles of segregation.

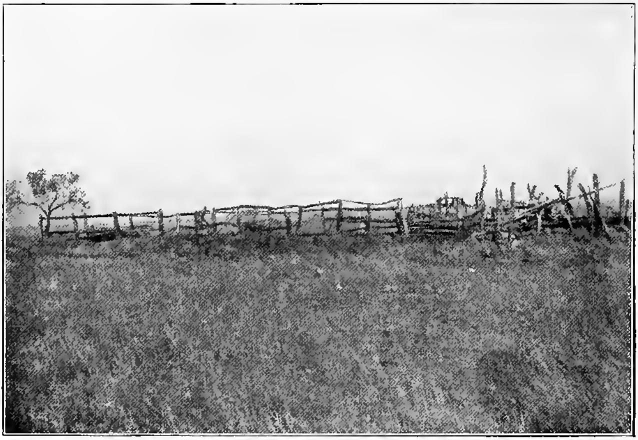
3. **The law of recombination.** The discovery of the principle of segregation was necessary to explain the fact of dominance, and it just as easily leads to the law of recombination. We have seen that the male and female germs are not simple, but are composed of various unit characters, which, in the production of the new germ, undergo the process of segregation. On the manner in which they recombine will depend the character of the resulting offspring. The law of segregation supposes that each pair of unit characters combines without reference to any other pair. Mendel applied his method of study to seven distinct characters in peas, and found that in each pair the inheritance was similar. Wherever the plant or animal

breeder is dealing with two distinctive characters, his course is fairly clear, because, in regard to these, the gametes, or germ cells, are of two kinds only, and, in combination, they will act as in the case of tallness and dwarfness in peas.

The importance of this fact is seen when it is stated that purity of type is solely dependent on gametic segregation and has nothing to do with the prolonged course of selection, as was and is believed by most stock breeders. The principles of Mendelism prove without any doubt whatever, the apparent paradox, that "an organism may be pure bred in respect of a given character, though its parents were cross bred in the same respect. Purity depends on the meeting of two gametes bearing similar factors, and when two similarly constituted gametes do thus meet in fertilisation, the product of their union is pure." Too much must not be understood from this quotation, for it is evident that an individual may be pure in respect to one character, and cross bred, or impure, in respect of others.

The practical application of Mendelism. It is comparatively easy to show the plant breeder that a knowledge of the Principles of Mendelism will assist him ; but it is not so with the stock breeder, who asks, What is its practical economical value to me in my work ? It is admitted that Mendelism cannot at present afford the breeder of show stock much, if any, assistance, but it undoubtedly offers suggestive help to the breeder seeking improvement by crossing.

The breeder knows that heredity is the basis of his work. Therefore he must recognise that any contribution to a more exact knowledge of what heredity is must prove of service to him. Already some striking results have been obtained. We know that heredity is a question of individuals, and that similarity of appearance in parents is no sure guide as to what the progeny will be like. The important point in cross-breeding is to consider the individual. This applies to the selection of parent stock, but particularly to the progeny. In the case of plants resulting from a cross, the seed of each individual plant of the F.1 generation must be kept separate and sown by itself. However much alike two plants may look, their seed must not be mixed; and, if they come true in the second or F.2 generation, they may be depended upon to continue to breed true. In



Remains of an Old-Time Stockyard.

other words: "every possible variety arising from a cross appears in the F.2 generation, if only a sufficient number is raised, and of all these different varieties a certain proportion of each is already fixed." The plant breeder is thus saved much labour, and is able to fix his varieties in the shortest possible time. The value of this fact in connection with raising new varieties of wheat, oats, barley, peas, etc., is very great.

Another important result of Mendelian breeding proves that the increased vigour which comes from a cross may be obtained without losing the purity of the old strain. Punnett says: "Most breeders are fully alive to the beneficial results of a cross so far as vigour is concerned, but they often hesitate to embark upon it owing to what was held to be the inevitably lengthy and laborious business of recovering the original variety and fixing it, even if in the process it was not altogether lost. That danger Mendelism has removed, and we now know that by working on these lines it is possible in three or four generations to recover the original variety in a fixed state, with all the superadded vigour that follows from a cross."

The difficulty with regard to breeding animals is very much greater, but it has been clearly shown that the same principles hold good here also, and again quoting from Professor Punnett: "There is no reason why the process of analysis, though more troublesome, should not be effectively carried out. At the same time, it affords the breeder a rational basis for some familiar but puzzling phenomena. The fact, for instance, that certain characters often skip a generation, is simply the effect of dominance in F.1, and the reappearance of the recessive character in the following generation. "Reversion" and "atavism," again, are phenomena which are no longer mysterious, but can be simply expressed in Mendelian terms. The occasional appearance of a sport in a supposedly pure strain is often due to the reappearance of a recessive character. Thus, even in the most highly pedigreed strains of polled cattle, such as the Aberdeen-Angus, occasional individuals with horns appear. The polled character is dominant to the horned, and the occasional reappearance of the horned animal is due to the fact that some of the polled herd are heterozygous in this character. When two such individuals are mated, the chances

A MODERN STOCKYARD, WHICH HAS TAKEN THE PLACE OF THE OLD-TIMER.

are one in four that the offspring will be horned. Though the heterozygous individuals may be indistinguishable in appearance from the pure dominant, they can be readily separated by the breeding test. For when crossed by the recessive, in this case horned animals, the pure dominant gives only polled beasts, while the heterozygous individual gives equal numbers of polled and horned ones.

" Suppose that a breeder has a chestnut mare and wishes to make certain of a bay foal from her. We know that bay is dominant to chestnut, and that if a homozygous bay stallion is used, a bay foal must result. In his choice of a sire, therefore, the breeder must be guided by the previous record of the animal, and select one that has never given anything but bays when put to either bay or chestnut mares. In this way he will assure himself of a bay foal from his chestnut mare, whereas if the record of the sire shows that he has given chestnuts, he will be heterozygous, and the chances of his getting a bay or a chestnut out of a chestnut mare are equal.

" It is not impossible that the breeder may be unwilling to test his animals by crossing them with a different breed through fear that their purity may be thereby impaired, and that the influence of the previous cross may show itself in succeeding generations. He might hesitate, for instance, to test his polled cows by crossing them with a horned bull for fear of getting horned calves when the cows were afterwards put to a polled bull of their own breed. The belief in the power of a sire to influence subsequent generations, or ' telegony,' as it is sometimes called, is not uncommon, even to-day. Nevertheless, carefully conducted experiments by more than one competent observer have failed to elicit a single shred of unequivocal evidence in favour of the view. Until we have evidence based upon experiments which are capable of repetition, we may safely ignore ‘telegony’ as a factor in heredity.”

PESTS AND DISEASES.

Survival of the fittest. All are familiar with the expression "the fittest will survive," but it is not always remembered that "fittest" does not mean the best from man's point of view, or the most highly developed in the scale of evolution. Animals, as well as plants, often survive, because of their degeneracy, or because of their objectionable qualities. Fitness, in this connection, means being adapted for resisting natural enemies, and for obtaining food. To eat and be eaten is one of nature's laws. The various kinds of ticks which are parasitic on fowls, cattle, sheep, and other animals, are examples of fitness to survive in consequence of degeneracy. The root borers, which have proved so destructive in the orchards at Doncaster and other places in Victoria, are merely proving their fitness to survive the destruction of their natural food, by adapting themselves to eating fruit trees instead of acacias and eucalyptus. The rabbit, the sparrow, and the starling, are pests, because they adapted themselves to their surroundings, and multiplied in the absence of natural enemies to keep them in check.

Natural law decrees that in a condition of nature the fittest will survive. Under the conditions of intense culture, the farmer, the stock breeder, the fruit grower, gardener, and the amateur flower lover, are each and all working against that law. In a state of nature, diseases and natural enemies destroy weakly plants and animals, and those only survive which are able to withstand their attacks, and so in the course of ages a condition of stable equilibrium is produced, which is only occasionally upset by extraordinary means, such, for example, as by a strange disease or a new enemy.

Artificial conditions. Our domestic animals and cultivated plants are, on the other hand, always in a condition of unstable equilibrium. Nature's standard of fitness is the power to survive the hundred and one diseases and foes. Man's standard is the possession of useful or desired qualities, some of which, not infrequently, are really evidence of weakly constitution and natural unfitness. Everyone knows how unsuited a plant reared and forced in a hot-house is for withstanding the ordinary conditions of the outdoor garden. In the same way a pampered pet poodle or other fancy dog is as unfit to live under the ordinary conditions of domestic dog life, as the average dog is to capture his living and survive the vicissitudes of the bush. In the same way the cultivated plants of our farms, orchards and gardens are quite as unfitted for the struggle for life under purely natural conditions as are hot-house plants for living in the open garden, or the domestic dog for winning a living in the forest. If all the domestic dogs were turned adrift those nearest to the wild dog in character would survive, but their characters would change. In the same way if a cultivated garden were left to nature, those plants most suited to the conditions of climate, soil and surroundings, would continue to propagate themselves, but would lose their fine cultivated characters, and the most highly esteemed varieties, such as the Washington navel orange, would die out in a few years.

Why pests and diseases have to be fought. It is very necessary that the farmer, orchardist, gardener, or stockman should remember the above principle in order that he may understand the liability of his crops to disease, and the ravages of parasitic foes which are ever ready for attack, and under favourable conditions often not easily distinguishable by the cultivator, assume the proportions of epidemics.

In a few words, the cultivator of crops, be they vegetable or animal, field or garden, big stock or poultry, must remember that he is carrying on his work under artificial conditions, or under a state of unstable equilibrium, which is constantly being upset, and so he must as constantly adopt means for maintaining the conditions which are profitable to him. To this end he must remember:

1. That prevention is better than cure.

2. That the more vigorous and healthy his plants or animals are the better are they able to withstand diseases and ward off the attacks of pests.

3. That in combating diseases and pests it is usually the first step which tells, so that the worker should not wait for an enemy to gain a firm footing before he adopts remedial measures.

4. Endeavour to restore the balance by the protection of natural enemies, insectivorous birds, predaceous and parasitic insects; and the cautious introduction of natural enemies and parasitic insects from the countries from which the pests came.

Cause and effect. The present subject is a difficult one to deal with briefly, accurately, and yet simply, because it is almost impossible to avoid confusion over cause and effect. Many of the troubles, loosely called diseases, with which the stock raiser, farmer, fruit grower and gardener has to contend with are merely the results of parasitic attacks. He is familiar with the effect, but the cause is hidden and often not known. A dog or a horse is affected with mange: the appearance and the effect of the disease are apparent and the owner desires a remedy. It is easy to prescribe the recognised treatment without touching the all-important fact that the disease as seen is merely the effect of a minute skin parasite. When the cause is understood the treatment becomes intelligible.

The farmer's wheat crop is affected with smut, and he is told to pickle his seed with sulphate of copper or formalin. He follows directions, but may find his next crop affected simply because, through not understanding that the disease is caused by a fungus which grows from a spore, and enters the tiny young plant and lives inside it, he has allowed his seed to become again infected with smut spores. The apple grower finds his apple trees unhealthy and his crop malformed, cracked, and more or less covered with black spots and scabs. This is the effect, the cause is a parasitic fungus called fusicladium. When he understands the nature of the disease, he realises the necessity of spraying his trees with Bordeaux mixture in the dormant season to kill the spores and so prevent an attack.

We cannot in this book deal with the treatment of individual diseases, nor is there any need to do so, because the Agricultural Departments of the various States have specialists whose duty it is to give advice as required, and excellent handbooks and bulletins containing particulars of the various recognised remedies may be had for the asking. Our purpose is to enable the student to more clearly understand the general principles governing the combating of pests and diseases affecting farm and garden crops, stock, etc.

Classification of pests and diseases. For convenience, we may classify the various agencies, usually called pests and diseases, which have to be combated by the agriculturist in his work of controlling nature for the purpose of producing animal and plant crops, under five heads:

1. The larger animal pests—indigenous and introduced—such as dingoes, foxes, rabbits, hares, crows, eagles, sparrows, starlings, rats, mice, etc. Some of these prey on one another and on the smaller insect pests, and do good as well as harm. They are not in themselves obnoxious. They are part of nature's system, and are pests only because they interfere with man's plans for using the products of the soil for his own purposes. The same argument of course applies to all pests. Trapping, shooting and poison are the

means generally relied on in the control of this class of pests.

2. Insects and their allies and small animals which prey upon the farmer's crops or render his home objectionable. In this section we have snails and slugs, which are molluscs; true insects, such as aphides, scale insects, plant bugs, ticks, caterpillars, beetles and their larvæ, fruit flies, blowflies, house flies, bot flies, house bugs, cockroaches, fleas; the minute creatures which cause mange, ringworm, itch, etc., and internal parasites, such as worms, fluke, hydatids and so forth.

3. Injurious plants, such as poison plants, parasitic plants like dodder, noxious weeds like nutgrass, star thistle, Bathurst burr. Harmless but useless weeds, such as stinkwort, sorrel, pimpernel, poppy, blind nettle. Plants in themselves good, but, on account of their free seeding and vigour, choking out or causing injury to crops, such as wild oats, cockspur, couch grass, etc.

4. Parasitic fungi and disease-producing bacteria. In this class we have rusts and smuts, often causing great injury to wheat crops; Irish blight and other diseases of the potato; fusicladium or "black spot" of the apple and pear; peach leaf curl; apricot shot-hole or scab; amthracnose and oidium of the vine; tomato black rot; and numerous others affecting nearly every cultivated crop.

5. Constitutional or physiological troubles. This class is a convenient method of concealing our lack of knowledge, when animals and plants become sick, fail to thrive, or die without our being able to find a reason.

The essential principle. It is important that the farmer, whatever be his special sphere of work, should endeavour to make himself familiar with the above broad classification. The first essential in combating a disease or a pest is to understand its nature. For this he requires a little general knowledge of natural history, especially correct general ideas about entomology and biology. A farmer need seldom trouble about scientific names, and for this reason few are being used here ; but he should not despise them, for they are really no harder to remember when they mean real things than are the names and pedigrees of race horses and stud stock. They are as necessary to the specialist as Christian and surnames are to people, and at times must be used to prevent confusion from inaccurate or misleading local names. When common names are distinctive and well known, the specialist should use them in speaking to the farmer. Stinking smut or bunt is quite as distinctive as *Tilletia tritici*. Codlin moth is as accurate for practical work as *Carpocapsa pomonella*. It would be well if all could be taught the general life histories of insects. The early or larval stage of butterflies and moths are caterpillars, *not* grubs or worms ; but it is doubtful if it be practically possible to alter the custom of speaking of the codlin moth caterpillar as a grub, or to change the common name of the nocturnal dirty green vine caterpillar, which buries itself during the day at the base of young vines and other plants, from "cutworm" to anything more descriptive. A worm is an entirely different order of animal, but an inaccurate name which people understand cannot be discarded readily. The larvæ of beetles are grubs, and strictly this term should be only used in this sense. The larvæ of flies are maggots, and are legless. Simple facts like these, if generally known, would save a good deal of confusion ; but they should be taught from specimens and not from books.

Look for the cause of disease. The farmer, the fruit grower and the gardener is familiar with the results of the attacks of various pests and fungus diseases ; but he is usually ignorant of the cause of the trouble. He should not be satisfied, and the Departments of Agriculture should not rest until he knows the general nature of the causes of his troubles. Literature in abundance is available, either for the asking, or at trifling cost ; but the difference between the reading of a thing and knowing it is as great as between the appearance of ringworm and the tiny creature that causes it. Owing to lack of knowledge of the causes of diseases, people do very absurd things. A farmer would laugh at the idea of using poisoned dingo bait to destroy stinkwort ; but it is not more ridiculous than using a fungicide to destroy insects or an insecticide to prevent fungus disease, things which scores of people do every year.

People, especially fruit growers and gardeners, often confuse the method of application with the remedy. They frequently quite fail to realise, for example, that spraying is a means of applying remedies, not a remedy itself. With few exceptions the remedies for insect pests are useless, or almost so, for fungous diseases, and remedies for fungus diseases are useless, or almost useless, against insect pests. Therefore, the first duty of the gardener is to learn to identify the cause of his trouble, and then consider the special treatment recommended for the particular or similar pest or disease.

Attack at the weakest point. A study of the life history of a pest will usually show that there is one period in its life when it may be attacked more easily than at others. In many cases it is useless to attempt to control a pest at any other time. For example, the mother locusts lay their eggs in a selected spot of clear ground, and, when the young hatch, they congregate in a dense crowd of small, comparatively helpless hoppers, which can be destroyed easily with a roller, fire, or kerosene spray. Every week they are allowed to live they are harder to deal with, but right through the larval stage, up to the time of their final moult, when they develop wings, they are hoppers, and their advance can be checked with screens or trenches, and they can be destroyed. When they start flying, man is powerless, for it is as easy to check the flowing tide on the seashore as a swarm of locusts on the wing.

Weeds are easily destroyed during the first few days after germination. At this stage a raking or a harrowing on a sunshiny day will destroy nearly all; but wait until they get a good roothold and the task becomes a difficult one. Of course it is easier to state a fact like this than to carry out the work in the stress of farm or garden operations, but the principle is right.

Internal and external fungi. Some fungus diseases live on the outside of their hosts, and these may be cured by the application of suitable fungicides. Of this class is oidium of the grape vine. More often, however, the fungus grows inside the tissue of the host plant, and when once it has gained an entrance it is largely or wholly beyond the reach of remedial measures, for anything that will destroy the parasite will kill the host. But while we cannot cure we may prevent; and this fact is another reason for the study of the cause and nature of diseases of plants and animals. We cannot cure smuts (there are many kinds) which cause so great a loss in cereal crops, in fact, the farmer cannot tell that his crop is affected until the damage is done. Prevention is, however, comparatively easy, and no good farmer now thinks of sowing seed wheat without treating it to destroy any smut spores which might be present. Fusicladium, or apple scab, which causes so much loss in moist seasons, belongs to this class, and the orchardist must spray as a preventive not as a cure. Irish blight of the potato may be largely prevented, but cannot be cured.

The importance of vigorous constitution. Another, and perhaps the most important, principle in connection with the treatment of animal and plant diseases, takes us back to the natural law of the survival of the fittest. While the stock breeder, general farmer, orchardist and gardener, can often do much in the way of artificial protection of his crops from diseases, and may in many cases use remedies to cure attacks, his aim should always be to raise stock and grow crops capable of resisting or escaping disease. A noted sheep breeder asserted this principle when he said, " The first essential in a ram is constitution, the second is constitution, and the third is again constitution, for without constitution all other qualities are of little value."

The fruit grower recognises it when he insists on all his apple trees being worked on "blight proof" stocks, *i.e.* stocks which are not attacked by the woolly aphis. The vine grower has found the use of phylloxera resistant stocks the only method by which he can carry on his industry in the presence of the phylloxera insect, which has resisted all attempts at eradication when once introduced. Wheat breeders are seeking for rust resistant and bunt resistant varieties; and the practical farmer seeks to grow early sorts which will wholly or largely escape infection in a rusty season.

Seek for disease-resisting strains. Whenever a crop is attacked by a pest or disease, the owner should examine it to see if any plants have escaped or resisted the attack, and these should be saved for further test. It is only under trial that resistance or immunity can be tested, and no opportunity should be lost of propagating disease-resisting varieties, which are also commercially good. Such work is of immense value to the community, and any good variety handled properly will prove profitable to its discoverer or originator. There is an enormous field for useful profitable work in this direction.

Provide favourable conditions. Another matter of the greatest practical importance is the necessity for providing stock and crops with favourable conditions to resist disease. Keep them healthy and they will largely resist the attacks of parasitic enemies. If stock are well fed and kept under wholesome and suitable conditions they will, as a rule, either not be attacked or are easily cured. Grow crops under suitable conditions, and they too will resist or escape disease to a very large extent. This is not always true; but often the apparent exceptions really prove the principle. A forced sappy plant may appear a picture of vigour, which is really evidence of weakness from a disease-resisting point of view.

Practical advice. A knowledge of the above principles will enable the farmer, fruit grower or gardener to conduct his operations with reason and judgment. It will not in itself prevent attacks or combat a disease. Knowing all about swimming will not save a drowning man, he must swim. Knowing why will help; knowing how is like having a gun and ammunition; but the cartridge must be put in the gun and the gun must be used with much patience and skill to save the sheep from the dingo. In few words it is very important to know the principles; but control of pests and diseases requires effort.

The writer once heard a deputation of potato growers request a Minister of Agriculture to have special search made for parasites to control the potato moth. Within a few feet of where the request was made was a potato field, from part of which the crop had been dug a week or so. It belonged to one of the speakers, and was strewn with the potato haulms and small potatoes infected with moth, while alongside was a growing crop of potatoes. Here was a man doing his very best to breed the pest and asking the

Government to find him a parasite to destroy it. In some cases parasites will do wonders, and they are not appreciated as they should be, but parasites are allies of Providence and help those who help themselves.

The principles we have outlined are of vast importance, but "knowledge is power" only when it is applied. The secret of the successful control of pests and diseases may be stated in a few words. Study the principles, obtain, from the Department of Agriculture of the State you are in, the special bulletins on prevalent pests and diseases, and apply the preventatives and remedies as recommended. Success depends on, first, Knowledge; second, Vigilance; third, Work.

SEASONS IN AUSTRALIA.

New settlers should follow the practices of experienced farmers. This being a book of principles, advice on the details of farm and garden operations has been as far as possible avoided. Agricultural methods might well form the subject of a special book; but it would be difficult to prepare, because operations vary so much in the different districts of each State of the Commonwealth. The old Australian settler knows the seasons and the work to be done in each month of the year under his special conditions. The new settler is advised to seek advice from successful men in the district in which he settles, and to follow their methods and practices. This applies to the Australian who goes from one State or one district to another as well as the immigrant from Britain, America and elsewhere. He will have ample opportunity for experiment later on, but he will be wise at all times to recognise the value of experience. This is one of the soundest principles in Agriculture:

> "Experience joined with common sense,
> To mortals is a providence."

As farming is very largely a matter of business, it is sound advice to any man, be he young or old, who finds himself working under new conditions, to use the experience of others rather than buy it at the cost of his own time and capital.

The immigrant from Europe, or from one State to another, is advised to go to the seedsmen in the various capital cities and procure copies of their catalogues, which contain calendars of seasonable operations for farm, orchard and garden. These set forth the times for seeding and planting operations as nearly as can be done in brief general statements; but the advice must not be followed blindly. It is intended to be varied more or less according to seasons and localities, a few miles often causing considerable difference in climatic conditions.

Climate. Australia is a compact continent nearly as large as Europe, extending from about 11° south of the Equator to beyond 39° south latitude, while Tasmania is still further south, the southern extremity being nearly 44° south. Hobart is about the same distance south of the Equator as Marseilles is north. New Zealand extends from about 34° to about 47° south latitude; so that the extreme north of the Dominion is nearly as near to the Equator as Sydney, and the city of Auckland is practically in the same latitude as Castlemaine, Victoria.

Latitude is, however, only one factor in climate, so that although roughly one-third of the continent is in the tropics, only the coastal portions of Queensland, the Northern Territory and the North West of Western Australia possess a distinctly tropical climate. By a tropical climate we understand heat associated with a moisture-laden atmosphere, and this combination is not found over the central portion of Australia, where the intense heat is rendered less trying by the dry atmosphere. Much of the difference between the climate of New Zealand and portions of Australia in corresponding latitudes is due to the proximity of the ocean, the character of the mountain system and the rainfall.

The region of summer rains. The rainfall of Australia is controlled by two main and several minor influences, and if these are explained, the general character of the rains and their relation to Agriculture will be the better understood. The northern section is under the influence of an equatorial or tropical rain system, so that the rainy season corresponds with the period of the year when the days are longest and the sun more directly overhead. It is this combination which causes the discomforts of the climate, and, at the same time, produces the luxuriant tropical vegetation of Queensland, and renders it so well suited for the growth of sugar cane and other tropical products. The cooler season of the year is comparatively rainless, and the climate is then pleasant. Summer rainfall conditions, due to more local influences, extend southward along the east coast right down to Gippsland in Victoria. The regions of summer rains correspond with the districts suitable for the growth of maize, sorghums, millets, cow peas, soy beans and such like crops, and where these thrive without irrigation, green summer pastures are also a prominent factor in Agriculture, and dairying is an important branch of farming. In other words, the east and south-east coastal districts of Australia have summer pastures, and summer fodder crops are easily grown because of the summer rains ; while in the west and south-west and southern coastal districts of the continent, where summer rains are absent or uncertain, these crops can only be grown successfully on a large scale with irrigation. This general fact is of great importance, and is not generally clearly understood by the public.

The southern or Antarctic belt of winter rains. The central and southern portions of the Australian continent are under the influence of the southern Anticyclonic or high pressure belt, which is the cause of the shortage of rains in the interior. Fortunately, the Anticyclonic path moves northward with the advent of the cool or winter season of the year, and this allows a corresponding northerly movement of the Antarctic low pressure belt which normally lies over the ocean to the south of Australia. The Commonwealth Meteorologist states that this yearly north and south oscillation amounts to about 600 miles, and is the controlling factor in providing the cool climatic conditions and regular winter rains over the southern portion of the continent.

As the high pressure area moves north, the influence of the winter "lows," or V-shaped depressions, is felt as they move from west to east, and it is under the influence of these that the rains fall. In Western Australia the heaviest rains usually fall in the early and midwinter months, and occur with wonderful regularity, usually starting in April and extending to October.

In the State of South Australia the rains over the agricultural areas, although not quite so regular, are of the same character. In addition, there is an increase in the number of irregular or summer rains under the combined influence of the southern extensions of tropical or monsoonal disturbances, and the occasional northern movements of Antarctic low pressure areas.

The western and northern portions of Victoria and the western slope districts of New South Wales are under the same influences as South Australia, but away from the coast there is a falling off in regularity.

In the central, western and northern interior of New South Wales, and the north of the central State, the rains lack the distinctive type previously mentioned, the irregularity being due to the fact that these portions of the continent are betwixt and between the zones of influence of the monsoonal and Antarctic rains, and while subject to both may not be blessed with either, and are much more liable to spasmodic thunder-storms during the summer months.

In Victoria, to the south and east of the ranges, the distinctive character of the rainfall, as seen in Western and South Australia, is disturbed by the geographical features of the country, and rains are much more regularly distributed through the year.

Roughly, Australia may be divided into three main rain belts, and a minor fourth :

1. The northern or tropical region of summer rains.
2. The southern or temperate area of winter rains.
3. The central neutral or uncertain area between 1 and 2.

This is the part of Australia most subject to drought.

4. The Eastern Coastal district receiving summer rains due to the special local conditions.

The following table shows the average monthly rainfall at typical stations in the different States. The figures are taken from Bulletin No. 4 of the Commonwealth Bureau of Meteorology.

MEAN MONTHLY PERCENTAGES, AND ANNUAL AVERAGE RAINFALL.

(*Note.*—The upper line is the average for the month, 100=1 inch. The lower line is the percentage.)

STATION.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly.	No. of Years.
Brisbane, Q., - -	667 13·8	714 14·8	658 13·6	397 8·2	310 6·4	274 5·6	239 4·9	248 5·2	201 4·1	283 5·8	364 7·5	481 10·0	48·36	49
St. George, Q., - -	319 14·7	276 12·7	247 11·4	172 7·9	181 8·3	130 6·0	109 5·0	89 4·1	146 6·7	163 7·5	142 6·5	197 9·1	21·71	19
Geraldton, Q., - -	2396 16·4	2079 14·3	2512 17·2	2099 14·4	1280 8·8	579 4·0	427 3·0	568 3·8	303 2·0	228 1·5	740 5·0	1364 9·4	145·71	22
Sydney, N.S.W., -	348 7·2	467 9·7	522 10·8	545 11·3	518 10·7	542 11·2	447 9·3	316 6·5	287 5·9	289 5·9	305 6·3	248 5·1	48·34	49
Dubbo, N.S.W., -	191 8·6	180 8·1	186 8·4	197 8·9	195 8·8	195 8·8	155 7·0	178 8·0	189 8·5	171 7·7	183 8·2	203 9·1	22·23	35
Bourke, N.S.W., -	195 12·9	191 12·7	157 10·3	137 9·0	108 7·2	107 7·2	86 5·7	86 5·7	98 6·6	109 7·2	130 8·7	115 7·8	15·19	36
Melbourne, Vic., -	188 7·4	172 6·8	213 8·4	238 9·4	211 8·3	209 8·2	185 7·3	180 7·1	231 9·1	268 10·5	224 8·8	224 8·8	25·43	54
Bendigo, Vic., - -	137 6·4	108 5·0	152 7·1	174 8·1	207 9·6	272 12·6	199 9·2	212 9·8	205 9·5	210 9·7	153 7·1	123 5·7	21·53	46

Hopetoun, Vic., -	55 4·7	64 5·4	82 7·0	112 9·5	118 10·0	163 13·8	108 9·2	123 10·5	114 9·7	102 8·7	69 5·8	66 5·6	11·74	11
Hobart, Tas., - -	183 7·9	150 6·5	162 6·9	173 7·4	180 7·7	216 9·3	215 9·2	181 7·8	209 9·0	217 9·3	256 11·0	187 8·0	23·29	64
Launceston, Tas., -	208 7·5	113 4·1	167 6·0	188 6·8	245 8·8	342 12·3	295 10·6	269 9·7	299 10·8	274 9·9	184 6·6	188 6·8	27·72	23
Waratah, Tas., -	476 5·6	374 4·4	521 6·2	643 7·6	746 8·8	950 11·2	961 11·4	893 10·6	887 10·5	823 9·7	635 7·5	544 6·4	84·53	24
Adelaide, S.A., - -	84 4·0	59 3·0	106 5·0	186 9·0	274 14·0	298 15·0	257 16·0	233 11·0	173 8·0	175 8·0	103 5·0	84 4·0	20·32	51
Mt. Gambier, S.A., -	157 5·0	93 3·0	147 5·0	256 8·0	346 11·0	412 13·0	420 13·0	412 13·0	306 10·0	255 8·0	183 6·0	173 5·0	31·60	47
Ororoo, S.A., - -	110 8·0	56 4·0	61 5·0	115 9·0	131 10·0	186 14·0	127 9·0	149 11·0	111 8·0	115 9·0	96 7·0	6 6·0	13·33	35
Perth, W.A., - -	34 1·0	34 1·0	77 2·3	170 5·1	490 14·7	662 20·0	629 18·8	564 17·0	330 10·0	207 6·2	78 2·3	60 2·0	33·35	32
Northampton, W.A.,	16 0·8	40 2·0	43 2·0	71 3·4	274 13·2	485 23·4	410 19·7	369 17·8	226 10·9	99 4·8	26 1·2	15 0·7	20·74	26
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